JOURNAL OF

CHEMICAL EDUCATION

VOLUME 28 | August, 1951 | NUMBER 8

GENERAL LIBRARY

Announcing the COLEMAN Model 19

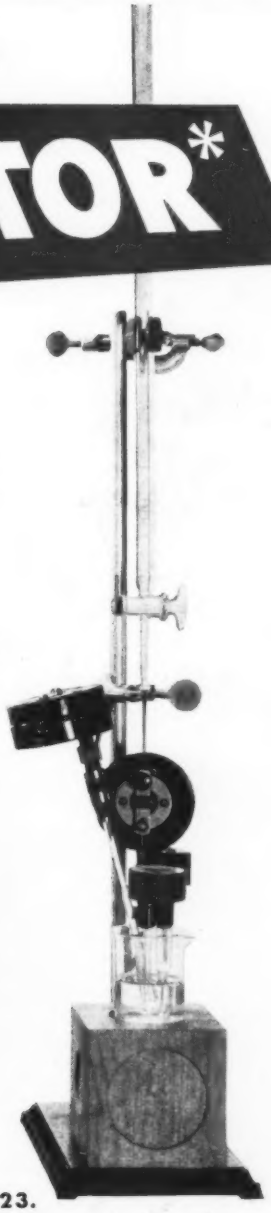
AUTOTRATOR*

A REALISTIC approach to automatic titration

FOR THE FIRST TIME—a **Practical** instrument for automatic performance of laboratory titrations. Practical, because it does a definite laboratory job, faster and better than it can be done manually; because it is easy to use; fits existing laboratory environment; meets actual laboratory needs.

FOR THE FIRST TIME—real savings, true economy from automatic operation, even for the small laboratory; because the Autotrator is properly priced, easy to use, practical for every-day laboratory operations; because it is rugged, dependable and ready for instant use.

Find out what *Realistic* design of automatic equipment can mean to *your* laboratory costs.



Write for Bulletin BB-223.

COLEMAN INSTRUMENTS 318 MADISON ST. MAYWOOD, ILLINOIS

*Trademark registered U. S. Patent Office.

What a Reagent Survey told us about you

In a recent widespread survey, you chemists told us a good deal about your likes and dislikes.

You *liked* 'Baker Analyzed' C. P. Chemicals and you ranked them as the No. 1 line of Laboratory Chemicals in *dependability*, in *known quality*, and in *availability*. That was fine praise, and *we liked it.*

Then, some of you told us some things you *didn't* like:

You asked us not to call our chemicals 'C. P.'—but to use the term 'Reagent.'

You felt that 'Baker Analyzed' Labeling could be improved. You wanted the actual analysis on the label, but you wanted it *in type* that could be more easily read. You also wanted the chemical name to appear in *bolder* display.

We welcome your suggestions and we're planning to follow them. Presently, you will begin to see the new 'Baker Analyzed' Reagent label, similar to specimen below.

Of course, the transition will have to be gradual. It will take a long time before all 'Baker Analyzed' Reagents reach you with the new label—for Baker distributors will continue to receive laboratory chemicals labeled both ways until this transition can be completed.

This new label is another contribution to the needs of the laboratory chemist by the makers of Baker Reagents, already first in dependability, first in known quality and first in availability. J. T. Baker Chemical Co., *Executive Offices and Plant:* Phillipsburg, New Jersey.

Baker CHEMICAL

Baker Chemicals

REAGENT • FINE • INDUSTRIAL

WARNING!

Causes Severe Burns to Skin and Eyes

Avoid contact with skin, eyes, and clothing.
Do not take internally.
When handling, wear goggles or face shield.
While making solutions, add Potassium Hydroxide slowly to surface of solution to avoid violent spattering.
In case of contact, immediately flush skin with plenty of water and wash with vinegar; for eyes, flush with plenty of water for at least 15 minutes and get medical attention.

POISON

Antidote - EXTERNAL: Flood with water, then wash with vinegar. If in eyes, wash with saturated boric acid solution. INTERNAL: Do not use emetics. Give water with large amount of diluted vinegar, lemon or orange juice. Follow with milk or white of eggs beaten with water. CALL A PHYSICIAN.

1 LB.(453.6g.)

1-3140

Potassium Hydroxide

PELLETS

KOH

F. W. 56.104

'Baker Analyzed' *REAGENT*

ANALYSIS OF LOT NO. 5150 MEETS A. C. S. SPECIFICATIONS

Assay (KOH)	88.8 %
Potassium Carbonate (K_2CO_3)	1.8 %
Chloride (Cl)	0.008 %
Nitrogen Compounds (as N)	0.0004 %
Phosphate (PO_4)	0.0004 %
Sulfate (SO_4)	0.001 %
Ammonium Hydroxide Precipitate	0.008 %
Heavy Metals (as Ag)	0.0005 %
Iron (Fe)	0.0004 %
Sodium (Na)	0.002 %

MADE IN U.S.A.

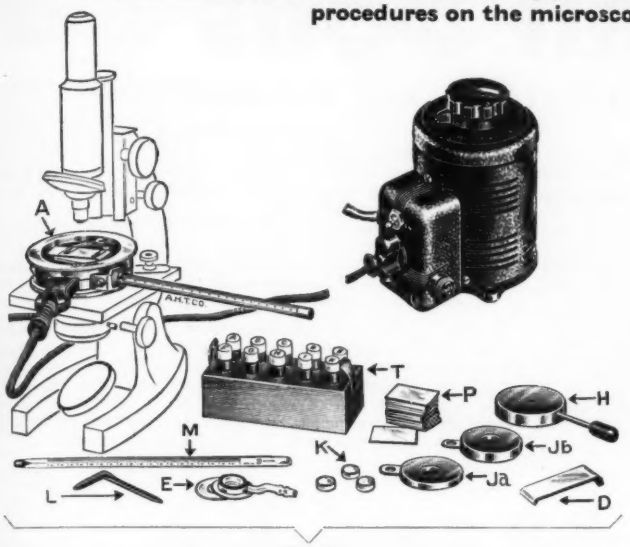
Baker CHEMICAL

J.T. BAKER CHEMICAL CO., PHILLIPSBURG, N.J.

A.H.T. CO. SPECIFICATION

KOFLER MICRO HOT STAGE

For determining corrected micro melting points and for general microchemical procedures on the microscope stage



6886-A.

8606.

KOFLER MICRO HOT STAGE (Micro Melting Point Apparatus), A.H.T. Co. Specification, electrically heated and with stage calibrated thermometers.

For determining corrected micro melting points by means of a microscope with samples as small as a single crystal, permitting continuous observation of changes in the sample before, during and after melting.

Useful also for general micro-preparative work, sublimations, measurements of refractive indices at elevated temperatures, fusions, heating under controlled conditions, etc., and physicochemical studies. See Ludwig Kofler, *Mikrochemie, Vol. XV (1934), p. 242;* and L. Kofler and A. Kofler, *"Mikro-Methoden zur Kennzeichnung Organischer Stoffe und Stoffgemische" (Innsbruck, 1948).*

For temperatures up to 350°C, with an accuracy of ±0.5°C in the range to 200°C and of ±1.0°C in higher range. Can be used with transmitted, reflected or polarized light on any compound microscope providing magnifications from 50 to 100× with objective having working distance of 6 mm or more, and preferably with a metal stage.

The apparatus consists essentially of an insulated, chromium plated metal stage, 90 mm diameter × 20 mm high, heated by an embedded Nichrome unit, and with a central light well fitted with a condensing lens system. A threaded post takes either a fork for the micro slide or various sublimation blocks. A variable transformer, with stop to limit output to approximately 80 volts and dial usable only over range from 0 to 80 in single divisions, permits exact reproduction of settings.

The two thermometers, ranges +30 to 230°C and +60 to 350°C, respectively, have been calibrated on the individual Hot Stage with which they are to be used. A set of eight stable test reagents is included with each outfit. They are convenient, not only in acquainting the user with manipulation of the instrument, but also for the preparation of a calibration chart for the transformer settings.

6886-A. **Micro Hot Stage, Kofler,** as above described, complete assembly as shown in illustration, i.e., Hot Stage A with glass cover, two calibrated thermometers M, cooling block H, Fischer sublimation blocks Ja and Jb, glass baffle D, three sublimation dishes K, Kofler-Dernbach vacuum sublimation chamber E, fork lifter L, twenty-four micro slides P, set of test reagents T, and variable transformer but without microscope; in case, with detailed directions for use. For 115 volts, 50 or 60 cycles, single phase a.c. only.... **236.00**

6887-A. **Ditto, Hot Stage A,** only, with two calibrated thermometers M, cooling block H, glass baffle D and variable transformer, but without case or other accessories..... **164.50**

CERTIFIED REFRACTIVE INDEX POWDERS, Kofler. A set of glass powders and minerals of accurately determined average refractive index, in intervals of approximately 0.01, for the determination of the refractive indices of fusions of inorganic or organic substances, or of liquids, in the range of 1.3400 to 1.6877, incl. For example, fusions prepared on the Kofler Hot Stage are tested by the well-known "Becke-Line" method in accordance with procedures developed by Dr. L. Kofler and his co-workers.

8606. **Certified Refractive Index Powders, Kofler,** as above described, range 1.3400 to 1.6877, set of twenty-four powders, each in glass tube containing sufficient for 200 tests, complete in wooden case with red glass filter and detailed directions for use..... **26.50**

More detailed information sent upon request.

ARTHUR H. THOMAS COMPANY

RETAIL—WHOLESALE—EXPORT

LABORATORY APPARATUS AND REAGENTS

WEST WASHINGTON SQUARE, PHILADELPHIA 5, PA., U.S.A.

Cable Address "Balance," Philadelphia

Announcing . . . a worthy addition to the ACS Monograph series

Alkali Soils

ACS MONOGRAPH No. 111

THEIR FORMATION, PROPERTIES AND RECLAMATION

by **W. P. KELLEY**

Professor Emeritus, Soil Chemistry
University of California, Berkeley

THIS monograph deals in considerable detail with a soil problem which, in recent years, is becoming of the utmost importance to vast agricultural areas. Dr. Kelley's researches are exhaustive and they provide a basis for dealing with the alkali soil problem which has heretofore been lacking. The book covers the problem and its solutions in terms of ion exchange—a field in which Dr. Kelley is renowned — and comparisons are drawn to the condition as it exists in the western United States and in Russia where much work has been done on the same subject.

Entirely new material and a completely up to date approach to the subject is found in the rather detailed consideration of:

(a) the effects of soluble salts on the soil itself and the resulting consequences on the growth of crops.
(b) the relation of irrigation to alkali soils, especially in regard to the spread of alkali in soils.
(c) the relation between the kind of salts that accumulate in alkali soils in their effect on the natural transformations to which alkali soils are subjected.
(d) the various means by which alkali soils of different types can be effectively reclaimed and . . .
(e) the methods of farm management by which the farmer may take full advantage of the new knowledge on the subject to the end that the reclamation can be made permanent.

Chapter 7 gives a full account of how to make practical use of the ideas in new knowledge set forth in this book. Furthermore, the basic researches of Hilgard and Gedroyz are discussed in great detail and all the pertinent evidence is presented and evaluated. This monograph will be essential to all soil chemists, agricultural chemists and agronomists and should rightly take its place beside the author's previous work "Cation Exchange in Soils."

1951, ACS Monograph, 168 pages, $5.00

Other New reinhold *Reference Books*

THE CONDENSED CHEMICAL DICTIONARY (4th edition) Turner

This famous reference book is now larger and more complete than ever. It covers all recent developments, new substances, trade names, uses, applications, formulas, properties, synonyms, derivations, containers, shipping instructions, safety regulations, and will be of utmost value to everyone needing quick, accurate information on chemicals and related materials.

1950, 760 pages, $12.00

PAINT FILM DEFECTS: Their Causes and Cure—Hess

This remarkably valuable book is the most complete compilation of paint defects and failures in existence. The contents are arranged as a reference work whereby Failure—Cause—Remedy appear under such sections as: Faults which develop during storage; Faults developed during application; Failures developing shortly after application; and Defects of Coatings on the finished objects when in use. This first English edition is based on the standard German work but it has been largely rewritten and enlarged. Many new sections connected with paint failures as they occur in typical damp climates and important developments in the raw material side of the paint and varnish industry have been added. This unique book will be of interest to paint manufacturers. It will save much time and money for paint users.

1951, 561 pages, $12.00

THE CHEMICAL TECHNOLOGY OF DYEING & PRINTING Volume II—Diserens

(Trans. and revised from 2nd German edition by Wengraf & Baumann)
With this book, the translators end the work they started in the first volume of this treatise. Volume II completes the survey of application of all the dyestuff groups omitted in the first volume. It includes the basic and substantive dyestuffs, pigments, and aniline black, as well as dyestuffs for acetate cellulose, nylon and other synthetic fibers. No other book on textile processing has ever presented so thoroughly the chemistry of the reactions occurring on fibers. Processes are clearly defined for the chemist, the dyer and the colorist. The text is complete with bibliographic literature and patent references.

1951, 450 pages, $12.00

THE CHEMISTRY OF THE NONBENZENOID HYDROCARBONS (2nd edition)—Brooks

Highlighting important advances in organic and petroleum chemistry, this new edition is a completely up to date survey of paraffins, olefins and cyclic (other than aromatic) hydrocarbons. It gives complete and extensive discussions of the chemistry, properties, methods of synthesis, thermal cracking, oxidation reactions, polymerization, alkylation and theoretical aspects of the many classes of hydrocarbons having a non-benzenoid structure. Advances made in the field in recent years are fully covered.

1950, 630 pages, $12.00

THE PHYSICAL CHEMISTRY OF LUBRICATING OILS—Bondi

This volume presents the latest ideas on the theory of lubricating oils and the physical chemical principles underlying their action. Written by an outstanding authority in the field, it should contribute greatly to the solution of many basic problems still confronting the practice of lubrication, particularly in wartime operation of airplanes and other automotive equipment. Such properties as viscosity, pour point, oiliness, flowing characteristics, foaming, etc. are discussed in great detail and attention is given to additives of all types. An entire chapter is devoted to synthetic lubrications and there is also an especially valuable section dealing with the reaction kinetics involved in lubrication problems. This book is addressed to engineers, physical chemists and all technical men in the field of lubrication.

1951, 400 pages, $10.00

BEET SUGAR TECHNOLOGY—McGinnis

This is the first comprehensive book in English on the manufacture of beet sugar in forty-four years. Presents in a coordinated and readable form all the information pertaining to the beet sugar industry. This volume was prepared by a group of experts. It covers in detail the history, economics and especially the chemical engineering methods used in this rapidly expanding industry. It describes the growing of sugar beets and the extraction methods used in foreign countries as well as in the United States. Special attention is devoted to the technical and agricultural aspects of the subject. This volume will become a standard work of reference for everyone in the sugar industry for many years to come.

1951, 580 pages, $10.00

Send for copies on approval

REINHOLD PUBLISHING CORPORATION • Dept. M-289 • 330 West 42nd Street, New York 18, N. Y.

Also Publishers of CHEMICAL ENGINEERING CATALOG, CHEMICAL MATERIALS CATALOG, MATERIALS AND METHODS, PROGRESSIVE ARCHITECTURE, Scientific, Technical and Architectural Books, and Advertising Management for the American Chemical Society Publications.

VOLUME 28

August, 1951

NUMBER 8

JOURNAL OF CHEMICAL EDUCATION

An Introduction to Radiation Chemistry, *Milton Burton* 404

The Congress at Karlsruhe, *Clara deMilt* 421

Karl Freudenberg, *Ralph E. Oesper* 426

Large Crystals of Monoclinic Sulfur, *Milton G. Wolf* 427

The Clausius-Clapeyron Equation, *Oliver L. I. Brown* 428

A Simple Electronic Relay, *John J. Pitha* 429

The Future of High-School Chemistry, *Elbert C. Weaver and Hanor A. Webb* .. 430

Niels Bjerrum, *Ralph E. Oesper* 433

Solubility of Sulfur: An Undergraduate Research Project, *Maxey Brooke* 434

Current Status of Departmental Libraries in Chemistry, *J. W. Broberg and R. E. Dunbar* 435

Titers, *Philip W. West* 437

It's Your Division 439

Proceedings of the Pacific Southwest Association of Chemistry Teachers Teaching Analytical Chemistry, *Louis Lykken* 440

The Effect of Nitrous Acid on the Oxidizing Power of Nitric Acid, *Robert C. Brasted* 442

Report of the New England Association of Chemistry Teachers Official Business 443

Editor's Outlook 403

Out of the Editor's Basket 27

Frontispiece—Niels Bjerrum 21

Recent Books 445

Advertisers' Index 39

Published by the
DIVISION OF CHEMICAL EDUCATION OF THE AMERICAN CHEMICAL SOCIETY

OFFICERS

J. A. Campbell — *Chairman*
H. N. Alyea — *Chairman-elect*
P. H. Fall — *Secretary*
F. D. Martin — *Treasurer*

NORRIS W. RAKESTRAW
Editor

Benjamin F. Gould
Advertising Mgr.

Joan Adgie — *Asst. to the Ed.*
Harvey F. Mack — *Business Mgr.*
C. S. Fleck — *Asst. Business Mgr.*
Evelyn Wright — *Circulation Mgr.*

BOARD OF PUBLICATION

J. A. Campbell — L. L. Quill
P. H. Fall — H. Hale
W. F. Kieffer

ASSOCIATE EDITORS

William E. Cadbury, Jr.
Haverford College
Haverford, Pennsylvania

Laurence S. Foster
Watertown Arsenal, Massachusetts

Joel H. Hildebrand
University of California

Kenneth A. Kobe
University of Texas

Henry M. Leicester
College of Physicians and Surgeons of San Francisco

Ralph E. Oesper
University of Cincinnati

G. Ross Robertson
University of California
Los Angeles, Calif.

B. D. VanEvera
George Washington University
Washington, D. C.

Elbert C. Weaver
Phillips Academy
Andover, Mass.

BUSINESS & PUBLICATION
20th and Northampton Streets
Easton, Pennsylvania

EDITORIAL OFFICE
Scripps Institution
La Jolla, California

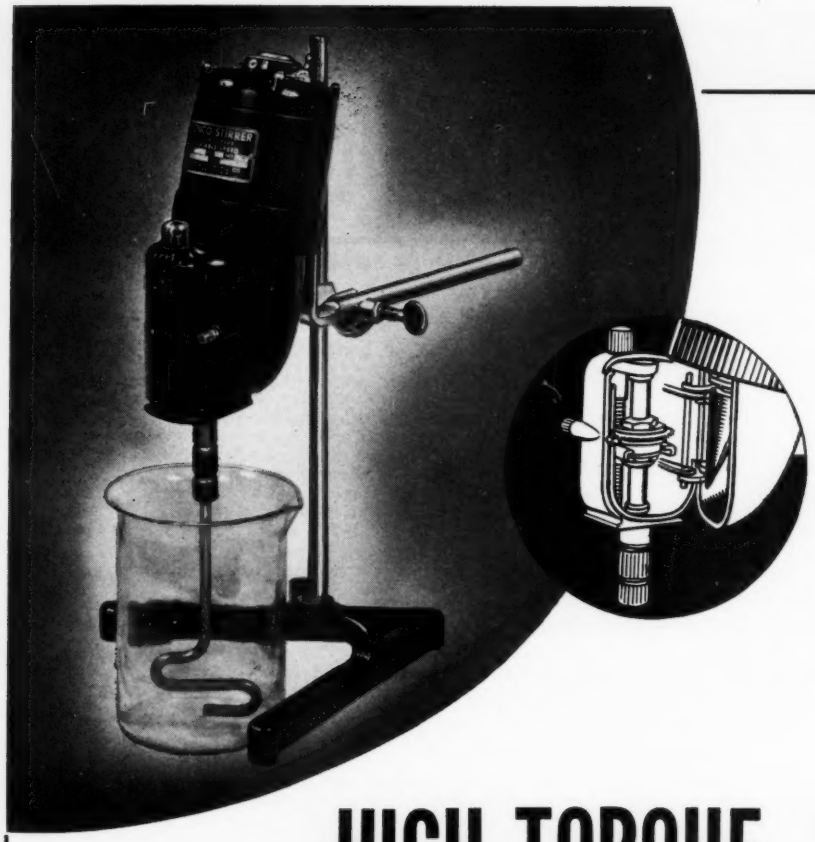
ADVERTISING OFFICE
500 Fifth Avenue
New York 18, N. Y.

Subscription Price: Domestic $3.00 per year; Countries in Pan-American Union $3.00 per year; Canada $3.50; other countries $4.00. Issued monthly. Single copies of issues in current year, 50c each; all other single copies, one dollar. Foreign remittances must be accompanied by International Money Order.

No claims for copies of journals lost in the mails can be allowed unless such claims are received within sixty (60) days of the date of issue and no claims can be allowed for issues lost as a result of insufficient notice of change of address. Manuscript for publication should be directed to the editor. Prospective authors are urged to avoid diffuse writing and to observe the forms outlined in our Notice to Authors of Papers as it appears on page 714 of the Dec. 1950 issue. Entered as second-class matter, January 31, 1924, at the Post Office at Easton, Pa., under the act of March 3, 1879. Accepted for mailing at special rate of postage provided for in Section 1103, Act of Oct. 3, 1917, authorized Jan. 31, 1924.

The JOURNAL OF CHEMICAL EDUCATION is the official organ of the Divisions of Chemical Education and History of Chemistry and incorporates the Report of the New England Association of Chemistry Teachers, and the Proceedings of the Pacific Southwest Association of Chemistry Teachers. It is indexed in the Education Index, Industrial Arts Index, and, in part, in the Quarterly Cumulative Index Medicus.

Copyright, 1951, by Division of Chemical Education, American Chemical Society



the Best for Laboratory Stirring

HIGH-TORQUE STIRRER

For dependable stirring of mixes that tend to change in consistency while being stirred, use the Cenco High-Torque Stirrer. Its special design gives maximum power transmission at constant speeds under varying load conditions. Normal speed range is from 100 to 1300 rpm, and from 25 to 325 rpm with the gear attachment. The improved chuck assures "hold fast" clamping and perfect aligning of the stirring rod. The fully-enclosed variable-speed mechanism avoids contamination of the mix. Stainless steel parts resist corrosion. Sturdy mounting rod permits easy clamping and positioning of the stirrer. Made for 115 or 230 volts AC or DC.

Write today for descriptive circular 1199

THE R.S.C. TULSA

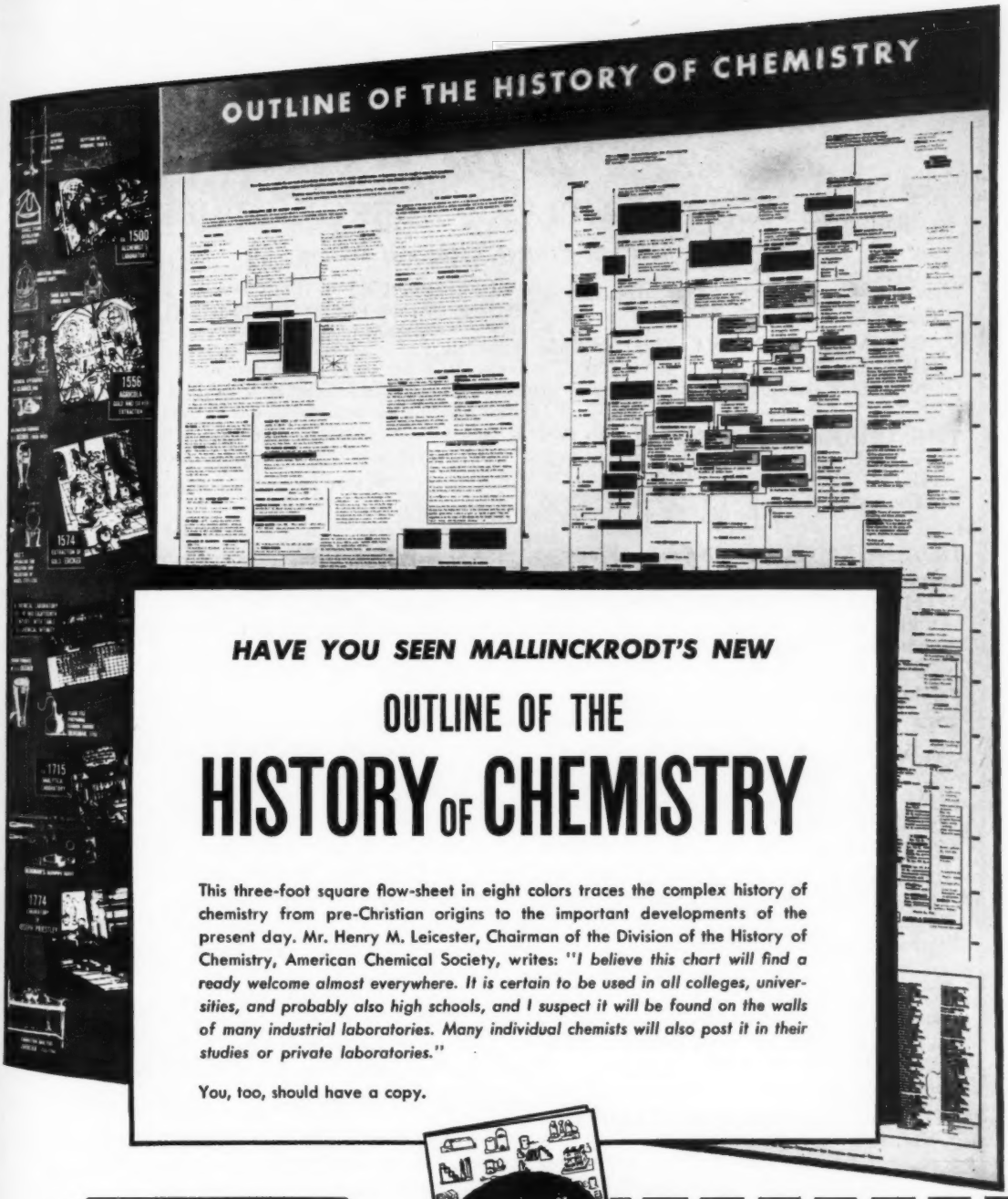
CENCO

CENTRAL SCIENTIFIC COMPANY

Scientific Instruments • Laboratory Supplies

1700 Irving Park Road · Chicago 13, Illinois

CHICAGO NEW YORK NEWARK BOSTON WASHINGTON DETROIT SAN FRANCISCO SANTA CLARA LOS ANGELES TORONTO MONTREAL VANCOUVER

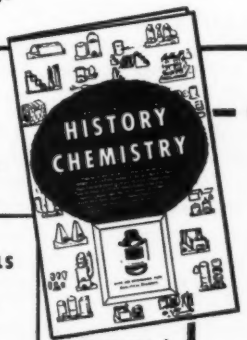


HAVE YOU SEEN MALLINCKRODT'S NEW

OUTLINE OF THE
HISTORY OF CHEMISTRY

This three-foot square flow-sheet in eight colors traces the complex history of chemistry from pre-Christian origins to the important developments of the present day. Mr. Henry M. Leicester, Chairman of the Division of the History of Chemistry, American Chemical Society, writes: *"I believe this chart will find a ready welcome almost everywhere. It is certain to be used in all colleges, universities, and probably also high schools, and I suspect it will be found on the walls of many industrial laboratories. Many individual chemists will also post it in their studies or private laboratories."*

You, too, should have a copy.



SEND FOR FREE COPY

Mallinckrodt®

MANUFACTURERS SINCE 1867 OF FINE CHEMICALS FOR MEDICINAL, PHOTOGRAPHIC, ANALYTICAL AND INDUSTRIAL PURPOSES

MALLINCKRODT CHEMICAL WORKS • ST. LOUIS • NEW YORK

Chicago • Cincinnati • Cleveland • Los Angeles • Philadelphia • San Francisco • Montreal • Toronto

MALLINCKRODT CHEMICAL WORKS, DEPT. 368
Mallinckrodt Street, ST. LOUIS 7, MISSOURI

Gentlemen: Please send me a copy of your new Outline of the History of Chemistry.

Name_____

Firm_____

Position_____

Street_____

City_____ Zone_____ State_____

McGraw-Hill Check List in the

NATIONAL NUCLEAR ENERGY SERIES

Manhattan Project Technical Section

Division I. Electromagnetic Separation Project

VACUUM EQUIPMENT AND TECHNIQUES. Vol. 1
Guthrie and Wakerling 264 pages, $2.50

THE CHARACTERISTICS OF ELECTRICAL DISCHARGES IN MAGNETIC FIELDS. Vol. 5
Guthrie and Wakerling 376 pages, $3.50

Division II. Gaseous Diffusion Project

ENGINEERING DEVELOPMENTS IN THE GASEOUS DIFFUSION PROCESS. Vol. 16
Benedict and Williams 129 pages, $1.25

Division III. Special Separations Project

SPECTROSCOPIC PROPERTIES OF URANIUM COMPOUNDS. Vol. 2
Dieke and Duncan 308 pages, $2.75

PHYSICAL PROPERTIES OF HEAVY WATER. Vol. 4A
Kirshenbaum and Urey In press

BIBLIOGRAPHY OF RESEARCH ON HEAVY HYDROGEN COMPOUNDS. Vol. 4C
Kimball, Urey, and Kirshenbaum
366 pages, $3.25

Division IV. Plutonium Project

RADIOCHEMICAL STUDIES: THE FISSION PRODUCTS. Vol. 9
Coryell and Sugarman 2151 pages, $18.50

THE TRANSURANIUM ELEMENTS. Vol. 14B
Seaborg, Katz, and Manning 1778 pages
(2 parts, not sold separately), $15.00

THE CHEMISTRY AND METALLURGY OF MISCELLANEOUS MATERIALS. Thermodynamics. Vol. 19B
Quill 329 pages, $3.00

INDUSTRIAL MEDICINE ON THE PLUTONIUM PROJECT. Vol. 20
Stone 536 pages, $6.25

HISTOPATHOLOGY OF IRRADIATION FROM EXTERNAL AND INTERNAL SOURCES. Vol. 22I
Bloom 808 pages, $8.00

TOXICOLOGY OF URANIUM. Vol. 23
Tannenbaum 333 pages, $3.00

Division V. Los Alamos Project

ELECTRONICS. Experimental Techniques. Vol. 1
Elmore and Sands 436 pages, $3.75

IONIZATION CHAMBERS AND COUNTERS. Experimental Techniques. Vol. 2
Rossi and Staub 243 pages $2.25

Division VI. University of Rochester Project

THE PHARMACOLOGY AND TOXICOLOGY OF URANIUM COMPOUNDS. Vol. 1
Voegtlin and Hodge 1084 pages
(2 volumes, not sold separately), $10.00

BIOLOGICAL STUDIES WITH POLONIUM, RADIUM, AND PLUTONIUM. Vol. 3
Fink 411 pages, $3.75

Division VII. Materials Procurement Project

PREPARATION, PROPERTIES, AND TECHNOLOGY OF FLUORINE AND ORGANIC FLUORO COMPOUNDS. Vol. 1
Slesser and Schram Ready in August

Division VIII. Manhattan Project (Analytical Chemistry and Uranium Chemistry)

ANALYTICAL CHEMISTRY OF THE MANHATTAN PROJECT: Uranium and Thorium. Vol. 1
Rodden 748 pages, $6.75

THE CHEMISTRY OF URANIUM. Vol. 5
Katz and Rabinowitch 632 pages, $7.25

Send for copies on approval

McGRAW-HILL BOOK COMPANY, Inc.

330 West 42nd Street New York 18, N. Y.

Leading Macmillan Chemistry Texts

FUNDAMENTALS of SEMI-MICRO QUALITATIVE ANALYSIS, Rev.

Kelsey & Dietrich

Representing a complete rewriting of the original text, this revision differs from its predecessor in its approach. Both the theoretical and analytical sections have been rewritten. At the end of each chapter and each analytical group, there are sufficient problems and exercises in the illustration and application of the principles presented to test the student's knowledge and his correlation of facts and principles. Rewriting achieves better correlation and permits the inclusion of modern ideas. Preliminary experiments have been included with each analytical group because of the appeal this approach has to a number of instructors. The authors presuppose a term of general chemistry. *To be published in August.*

Introductory COLLEGE CHEMISTRY Fifth Edition

Holmes

Designed for first year college chemistry courses this text is intended for instructors desiring a book a little shorter and less rigorous than Holmes' *General Chemistry*. This revision is designed to satisfy the needs of all beginning chemistry students. The first three chapters are largely rewritten with the Valence chapter reset. More emphasis is placed on the influence of the structure of the atom. Hydrogen instead of oxygen is selected as the first element for study and atomic energy and fission are given much more extended treatment. Titanium metal with its promise of great usefulness is stressed in order to stimulate the students' interest in properties of metals. Applications to industry are based on theory. *Published in June—$4.75*

FUNDAMENTAL PRINCIPLES of PHYSICAL CHEMISTRY, Rev.

Prutton & Maron

This basic text for college courses in Physical Chemistry offers many new changes in revision: the addition of a chapter on Photochemistry, a check of problems and an increase in their number by over 30%, the deletion of material considered nonessential, the revision of constants to latest best values, revision of chapter on Atomic Structure and Radioactivity, the introduction where possible of newly accepted absolute electrical units, the addition of a table of best values of physicochemical constants, the revision of all references for further study, the introduction, in connection with crystal structure, of concepts of space lattice and space group, the insertion of a section on Donnan equilibrium. *Published in July.*

THE MACMILLAN COMPANY, 60 Fifth Ave., N. Y.

Please mention CHEMICAL EDUCATION *when writing to advertisers*

The Handiest Set Ever Made

Set No. 1241 50 gram x 10 mg. Total weight capacity 101 grams.

OHAUS Laboratory Weights

In New, Modern

Clear-View

Plastic Case

50 gram to 10 mg., complete with Stainless Steel Forceps

At the Amazingly Low Price of

$2.75 *per set*

Perfect for School and Industrial Use

At the amazingly low price listed, it will pay you to have a set of these weights for every balance you use. In the new, modern Clear-View plastic case, weights are well protected yet clearly visible through the transparent lid. Each weight has its definite place in the shrink-proof bakelite insert, holes do not distort, weights do not stick. Furthermore, the set has been designed so that the lid prevents the weights from falling out of place when the box is inverted. The complete set is a compact and attractive unit which will easily fit into the drawer of an analytical balance case.

Every weight is individually adjusted to well within Bureau of Standards Class "C" tolerances, the accuracy required for test weights used by Sealers of Weights and Measures. The weights from 1 to 50 gram are made of highly polished lacquered brass; fractional gram weights are satin finished aluminum. Each weight is clearly marked for easy identification.

The forceps supplied are made of highly polished stainless steel, and were designed for easy handling of the smallest weights. They will prove their worth in handling the weights, and as a generally useful laboratory instrument.

Available at Laboratory Supply dealers throughout the United States and Canada.

We invite your inquiry for additional information and name of laboratory supply dealer nearest you.

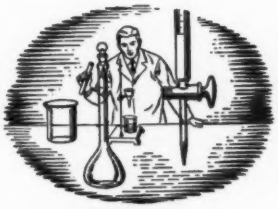
OHAUS SCALE CORPORATION 1050 COMMERCE AVE. UNION, N. J., U.S.A.

Laboratory Scale and Weight Specialists Since 1907

CONGRATULATIONS TO THE

ACS

ON ITS 75TH ANNIVERSARY



Merck & Co., Inc. is happy to extend congratulations to the American Chemical Society for its many outstanding contributions to the chemical profession. We are proud to be one of the original corporate members of the A.C.S.

The year 1951 also marks the introduction of the Society's new edition of *Reagent Chemicals*, and special recognition is due the Committee on Analytical Reagents for its exceptional work. The specifications established by the committee are playing a fundamental role in the advances of chemistry by defining the limits of impurities in standard reagents, thereby contributing to more uniform laboratory data.

Today, as in the past, we take pride in the fact that Merck Reagent Chemicals have consistently met A.C.S. standards wherever such specifications have been established.

Merck Laboratory Chemicals

MERCK & CO., INC.
Manufacturing Chemists
RAHWAY, NEW JERSEY
In Canada: MERCK & CO. Limited—Montreal

LOOK AT THE ADVANTAGES YOU GET WITH THE B&A SAFTEPAK†

FOR REAGENT HF

SETTING THE PACE IN CHEMICAL PURITY SINCE 1882
B&A
STANDARD OF PURITY
ACID HYDROFLUORIC
Reagent 48% Code 1100
GENERAL CHEMICAL DIVISION
NEW YORK N. Y. U. S. A.

1 Only B&A Saftepak Pours Drops or Full Flow Accurately

Pours exactly what you want—no more, no less. Whatever you want—drops, needle stream or full flow—the B&A Saftepak pours with complete precision. No surge . . . no dribble . . . no spill-over to upset accurate calculations.

2 Only B&A Saftepak Has the "Safte-Seal"

Simple plastic seal over pouring spout enables user to "customize" dispenser to his personal needs. No parts to get out of order. No broad pouring lip to complicate accurate dispensing.

3 No Contamination

Special "shielded" design of pour-out makes contamination of reagent acid virtually impossible. No open mouth or inner ledges on pour-out to collect dirt and dust.

4 Pours Safely

Special "siphon-action" pour-out draws back into bottle any drops clinging to lip when pouring stops.

5 Easy-to-Handle

The B&A Saftepak, with sturdy encircling label, fits conveniently into your hand for easy pouring.

6 Acid Resistant

Bottle and pour-out spout made of polyethylene—inert to aqueous HF.

7 Shatter-Proof

Bottle is pressure-molded. Shatter-proof plastic does not become brittle, crack or break as do ordinary wax containers.

8 Screw-Tight Cap

Provides easy reclosure; safeguards against possible spillage or leakage.

BAKER & ADAMSON ORIGINATED and introduced plastic dispensers for B&A Reagent Hydrofluoric Acid six years ago. Today, laboratory chemists all over America specify the B&A Saftepak when they order HF for laboratory use. They know this advanced package meets their needs in every respect.

IF YOU have not yet used B&A Reagent HF in the Saftepak dispenser, order it from the nearest Baker & Adamson office today. †General Chemical Trade-Mark

REAGENTS
B&A
STANDARD OF PURITY
FINE CHEMICALS

BAKER & ADAMSON *Reagents*

GENERAL CHEMICAL DIVISION
ALLIED CHEMICAL & DYE CORPORATION
40 RECTOR STREET, NEW YORK 6, N. Y.

Offices: Albany • Atlanta • Baltimore* • Birmingham* • Boston • Bridgeport* • Buffalo* • Charlotte* • Chicago* • Cleveland* • Denver* • Detroit* • Greenville (Miss.) • Houston* • Jacksonville • Kalamazoo • Los Angeles* • Minneapolis • New York* • Philadelphia* • Pittsburgh* • Providence* • St. Louis* • San Francisco* • Seattle • Yakima (Wash.)
In Wisconsin: General Chemical Company, Inc., Milwaukee, Wis.
In Canada: The Nichols Chemical Company, Limited • Montreal* • Toronto* • Vancouver*
SETTING THE PACE IN CHEMICAL PURITY SINCE 1882
* Complete stocks are carried here

TWO STAR PERFORMERS *For Your Laboratory*

★ Lanco YELLOW FLASH HIGH VISIBILITY THERMOMETER

MINIMIZE ERRORS IN TEMPERATURE READINGS

—sharp contrast of black figures on a bright yellow background.

—the yellow backing excludes confusing side lights and distorting reflections.

—tubes are 6mm (outside diameter) and have uniform mercury bores.

Because of the sharp contrast of black figures on a bright yellow background, Lanco Yellow Flash Thermometers are far easier to read with a greater degree of accuracy and much less danger of error than ordinary thermometers.

Thermometers are packaged as shown in a special 3-thermometer carrier-carton with a grooved corrugated insert. Single thermometers come in individual cardboard tubes.

PRICES AND DETAILS

No. CE-39691—CENTIGRADE 76 mm Immersion			
Range °C	Divisions C	Length mm	Price ea.
−15 to 110 C	1° C	305 mm	$1.65
−15 to 150 C	1° C	305 mm	1.65
0 to 205 C	1° C	305 mm	2.20
0 to 260 C	1° C	381 mm	2.40
0 to 360 C	1° C	381 mm	3.00
0 to 405 C	1° C	381 mm	3.30

No. CE-39698—FAHRENHEIT 3" Immersion			
Range °F	Divisions F	Length mm	Price ea.
−30 to 120 F	1° F	305 mm	$2.00
0 to 230 F	2° F	305 mm	1.65
0 to 300 F	2° F	305 mm	1.65
30 to 400 F	2° F	305 mm	2.20
30 to 600 F	2° F	381 mm	3.00
30 to 760 F	2° F	381 mm	3.30

DISCOUNT SCHEDULE

In lots of 3 of one range	Lots of 12	Lots of 24	Lots of 36	Gross lots
Less 5%	Less 10%	Less 20%	Less 25%	Less 30%

Ranges may be assorted in multiples of three to obtain the quantity discount.

All ASTM Thermometers Available in Yellow Back

Also available—Lanco Yellow Flash Total Immersion Thermometer

★ LANCO RUBBER TUBING

MAXIMUM PURITY

(Sp. Gr. 98) LANCO All-Latex Tubing is compounded to provide a purer, stronger, more elastic tubing for bacteriological work . . . food testing . . . and countless special procedures in organic or inorganic analysis. It is practically pure gum and non-toxic, suitable for repeated sterilization. Resistant to aging and light deterioration.

GREATER STRENGTH

(4500 lbs/sq. in.) LANCO All-Latex Tubing is made without seams to tear and break and because of its composition, the unusual strength of this tubing is possible. Latex tubing is stronger, yet proportionally lighter in weight than ordinary "rubber" tubing—an important advantage in the laboratory.

MORE ELASTICITY

(850% Elongation) LANCO All-Latex Tubing can be subjected to more than average stretching and still retain its shape. As is only possible with purest latex, it is soft and pliable and will give long satisfactory service due to extraordinary elasticity and resilience. Its use assures practically airtight seals.

Size inches	I.D.	1/8	1/8	3/16	3/16	3/16	3/16	1/4	1/4	1/4
	Wall	1/32	1/16	1/16	3/32	1/8	3/16	1/16	3/32	1/8
Amber No. CE-36390 Price Per Foot		.08	.11	.12	.19	.22	.26	.13	.20	.25
Black No. CE-36389 Price Per Foot		.09	.12	.13	.21	.25	.32	.16	.22	.27

Size inches	I.D.	1/4	5/16	5/16	3/8	3/8	1/2	5/8	3/4	1
	Wall	3/16	1/16	3/32	1/16	3/32	1/8	1/8	1/8	1/8
Amber No. CE-36390 Price per Foot		.40	.15	.23	.20	.26	.42	.55	.65	1.15
Black No. CE-36389 Price Per Foot		.43	.18	.25	.23	.30	.46	.64	.70	1.35

DISCOUNTS 48 feet of one size 10% 96 feet of one size 20%

CHEMICALS

ARTHUR S. LaPINE AND COMPANY, LaPINE **121 W. HUBBARD ST., CHICAGO 10, ILL.**

LABORATORY SUPPLIES-EQUIPMENT

SARGENT SLOMIN

Electrolytic Analyzers

★ **Immediate shipment from stock**

FOR HIGH SPEED QUANTITATIVE ANALYSIS OF

Ferrous and non-ferrous metals and alloys.
Electroplating solutions and electro-deposits.
Ores and minerals.
Metals in biological materials.
Metals in foods, soils, etc.
Forensic materials.
Micro and semi-micro specimens.

Designed for continuous trouble-free performance

The Sargent-Slomin Electrolytic Analyzers have through long service proved their value to analysts. Each unit is mounted within a case consisting of one-piece stainless steel panel, beaker platform and apron with sturdy end castings. All models are completely self-contained and operate from 50-60 cycle electric circuits — no auxiliary generators or rheostats are required.

The two position analyzers consist of two complete, independently operating analyzer circuits. Duplicate or check analyses can be run at the same time or two different analyses can be run simultaneously at different current densities.

The central electrode is rotated by a new capacitor type induction motor, operating at 550 r.p.m., especially engineered for this application. Under development for five years, this motor has been thoroughly tested and approved for continuous operation. Fully enclosed for protection against corrosive fumes—the shaft, sleeve bearings, and cap are made of stainless steel.

Outstanding features of this rugged motor are:

Greater output than any motor of similar characteristics and size.

No internal switches or brushes.

No "permanent" magnets — full output for long service life.

No speed change with change of load.

All parts of the new electrode chucks are made of stainless steel. A simplified design utilizes a positive retaining spring which permits quick, easy insertion of the electrodes and maintains proper electrical contact.

These new analyzers used with the specially designed high efficiency corrugated electrodes rapidly produce smooth, close grained deposits at maximum current density.

S-29460 ELECTROLYTIC ANALYZER — Sargent-Slomin, One Position. For operation from 115 Volt, 50-60 cycle circuits **$275.00**

S-29465 ELECTROLYTIC ANALYZER — Sargent-Slomin, Two Position. For operation from 115 Volt, 50-60 cycle circuits **$425.00**

S-29632 ANODE—Platinum gauze, Corrugated Form, High Speed. (Patent pending). Price subject to market.

S-29672 CATHODE — Platinum gauge, Corrugated Form, High Speed. (Patent pending.) Price subject to market.

SARGENT

SCIENTIFIC LABORATORY INSTRUMENTS • APPARATUS • CHEMICALS

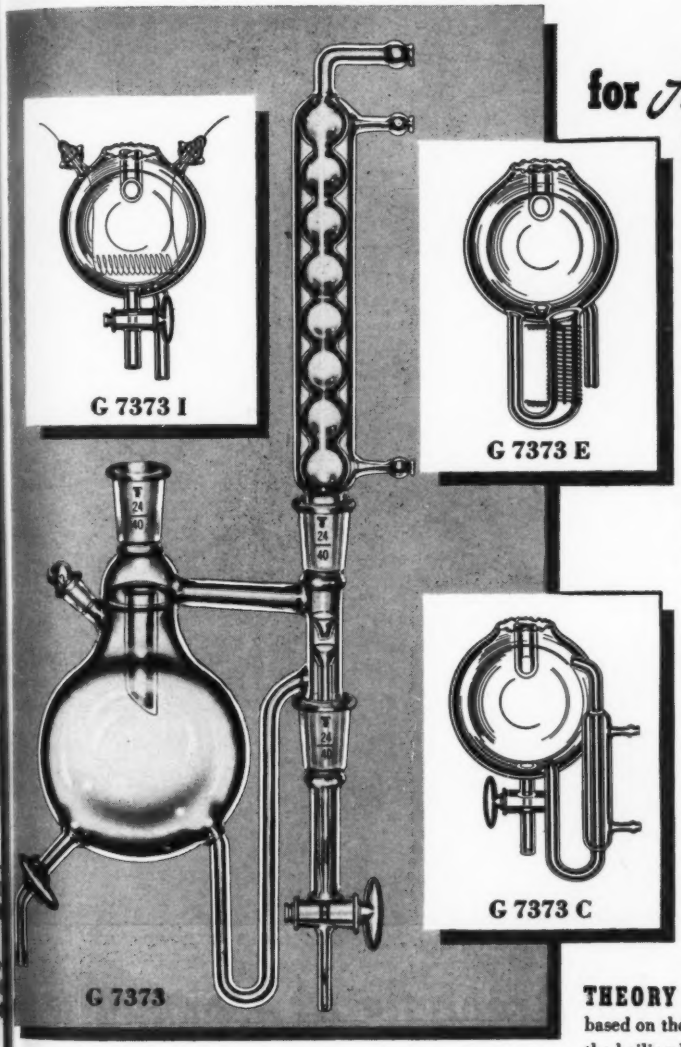
E. H. SARGENT & COMPANY, 4647 W. FOSTER AVE., CHICAGO 30, ILLINOIS

MICHIGAN DIVISION, 1959 EAST JEFFERSON STREET, DETROIT 7, MICHIGAN

SOUTHWESTERN DIVISION, 5915 PEELER STREET, DALLAS 9, TEXAS

the New, Improved *Othmer* still

for *Accurate* Determination of Vapor-Liquid Equilibrium



For the design of equipment and the analysis of problems in the field of distillation and related unit operations, vapor-liquid equilibrium data are essential. The most *accurate* and *convenient* way of obtaining these data are with an equilibrium type still as exemplified by the all-glass Othmer design.

The new improved Othmer Still* is the latest development of Dr. D. F. Othmer, of the Polytechnic Institute of Brooklyn, one of the foremost authorities on equilibrium stills. The Emil Greiner Company has manufactured many of these stills, which have found wide application in engineering research and have become standard pieces of laboratory equipment. We have also cooperated with Dr. Othmer in the manufacture of modifications of his still for specialized applications. For this reason, we are prepared to provide free consultation for the development and manufacture of any specialized stills you may require, in addition to the Standard Othmer stills listed.

G 7373—*Distilling Apparatus, Improved Othmer, Vapor-Liquid Equilibrium, Pyrex Brand Glass*, for direct external heating. Complete with reflux condenser, T-24/40 joint, and distillate trap receiver, T-24/40. T-24/40 on top of boiler flask and T 12/18 with plug at side. Each 55.50

G 7373 C—*Additional Reflux Cooler for* G 7373, small heat exchanger on reflux tube to boiler. Each 9.50

G 7373 E—*Additional External Electrical Heater for* G 7373, 250 watt nichrome wire wound on one leg of "U" shaped projection. Each 10.50

G 7373 I—*Additional Internal Electrical Heater for* G 7373, 250 watt nichrome element is inserted through two 18-9 ball joints with sealed-in platinum contact wires. Each 11.00

Note: Additional cooler or heaters if desired must be ordered at the time of ordering STILL, since they are incorporated as an integral part of the STILL.

Inquiries as to specially constructed STILLS are invited.

THEORY OF OPERATION The operation of these stills is based on the reflux equilibrium principle. Vapors in equilibrium with the boiling liquid mixture in the boiler are completely condensed into a distillate trap and the overflow from the trap is refluxed to the boiler. When the composition and quantity of vapor leaving the boiler is exactly equal to the composition and quantity of distillate returning to the boiler, equilibrium is established and the boiling point remains constant under the total pressure imposed on the systems. Samples of the liquids in the boiler and trap are then removed for chemical or physical chemical analysis to determine the compositions of the respective liquid and vapor phases in equilibrium.

*Othmer, D. F., *Anal. Chem.* **20**, 763 (1948)

The EMIL GREINER Co.

20-26 N. MOORE STREET E&G Co. NEW YORK 13, N.Y.

KIMBLE EXAX RETESTED Cylinder No. 20030; Flask No. 28015; Burette No. 17030

Tools of Science in the Arsenals of Democracy

THE "WIDTH" of our armed forces is measured by the fronts on which they are deployed.

The "depth" of our armed forces is measured by the miles from the front to the innermost reaches of our productive capacity.

Back of the men and machines that pour out the sinews of war in such tremendous volume stand the research laboratories. There, scientists minutely check the quality of products before they are released to those who use them in defense of democracy. There, too, scientists probe unceasingly to improve present weapons and supplies and develop new ones.

The meticulous work of thousands of scientists in these essential laboratories would dwindle, then die, without their tools—scientific instruments.

Kimble is humbly proud that the scientific instruments it produces have, in peace and war, been worthy tools in the hands of scientists everywhere.

In the turbulent times ahead, we shall do everything in our power, and ask the aid of everyone in control, to keep our nation's scientists supplied with the precision instruments we make to be weapons, as well as tools, in their hands.

KIMBLE GLASS TOLEDO 1, OHIO

Division of Owens-Illinois Glass Company

Please

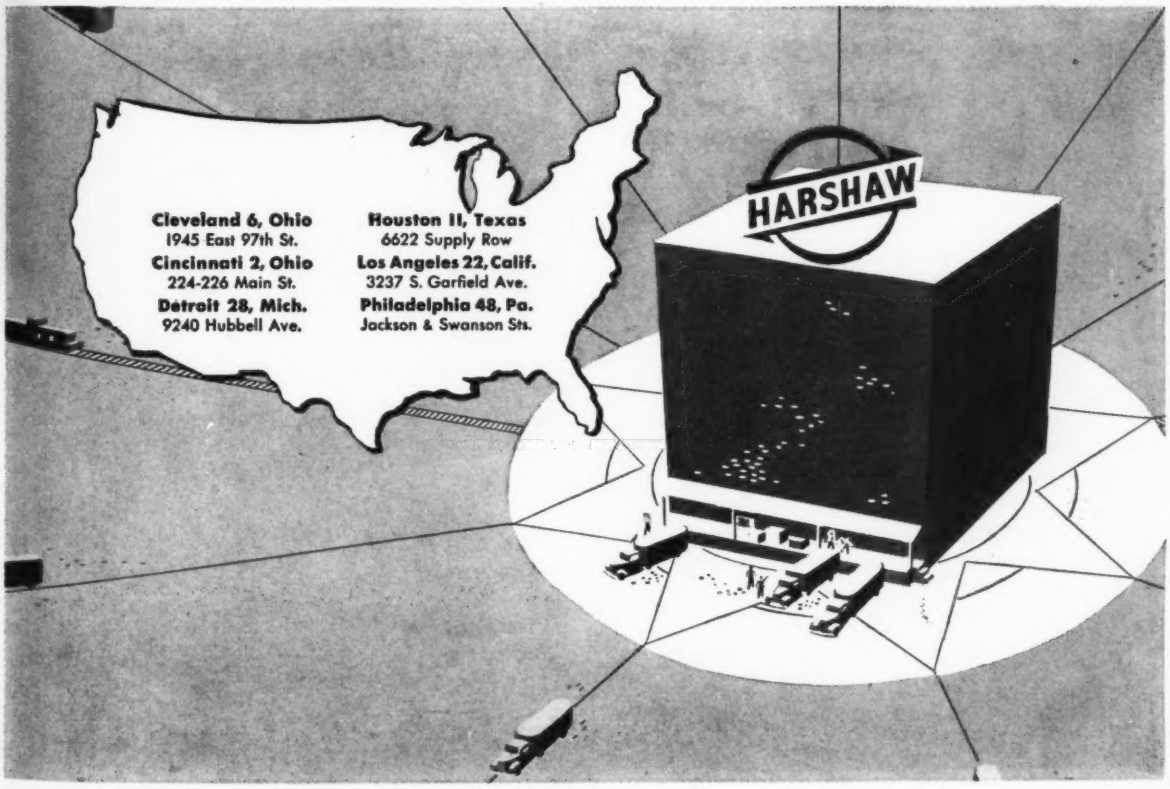
Make your Choice–

THEN DEPEND ON HARSHAW SCIENTIFIC TO SUPPLY IT

All 6 Harshaw Scientific Offices maintain warehouse stocks of laboratory instruments, apparatus, and chemicals—in fact, *thousands* of different items . . . good, recognized items.

We'll ship your material from our branch nearest you . . . and there *is* one within fast shipping distance of you.

HARSHAW SCIENTIFIC
DIVISION OF THE HARSHAW CHEMICAL CO.
CLEVELAND 6, OHIO



To read calibrations . .
To observe reactions . .
from a distance

EBERBACH CATHETOMETER permits you to read calibrations, to make measurements or to observe reactions from a distance—very important when working with dangerous materials or equipment. The telescope with crosshair gives 20X at 30 cm. and 8X at infinity. For vertical or horizontal applications this versatile instrument is available in 2 models—with 40 cm. or 100 cm. scale. Prices are reasonable—$150.00 and $250.00. Send for complete information.

Eberbach CORPORATION
SCIENTIFIC INSTRUMENTS & APPARATUS
ANN ARBOR, MICH. ESTABLISHED 1849

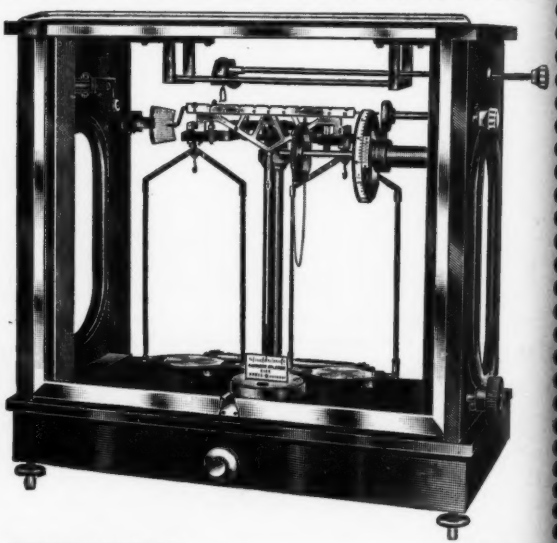
*WHY STRUGGLE **

WITH POOR EQUIPMENT?

Certainly nothing can be more "penny wise & gram foolish" than trying to get along with old, worn out or obsolete balances. With present day high speed requirements, you can't afford to use balances that do not give accurate reproductive results, efficiently. Nothing is more aggravating to the skilled scientist or technician than to have to struggle with instrumentation that is no longer capable of producing results with absolute precision that is so essential to fine craftsmanship. Check your balance requirements today and replace those obsolete instruments with modern time saving ABC analytical balances.

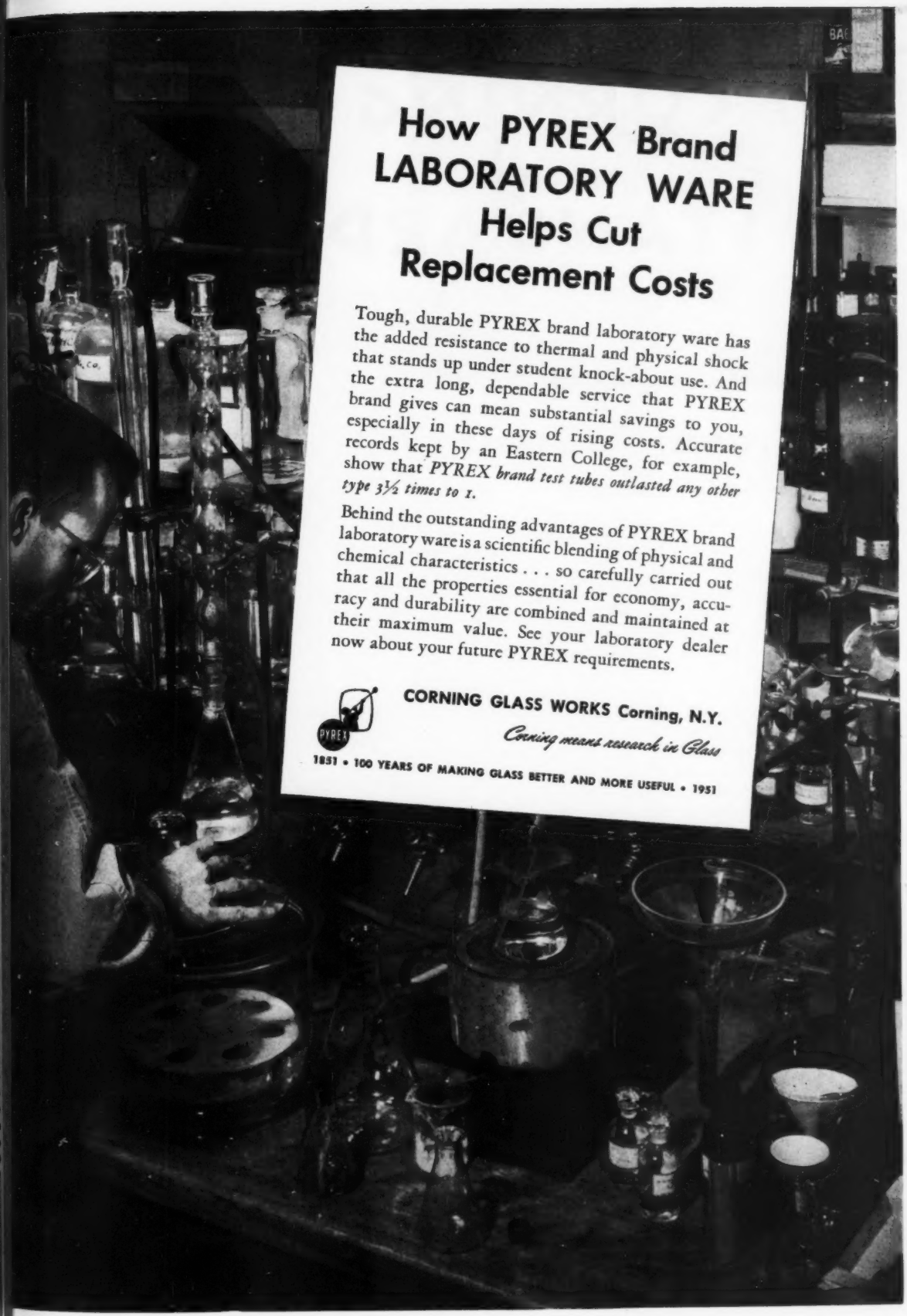
Write for catalog

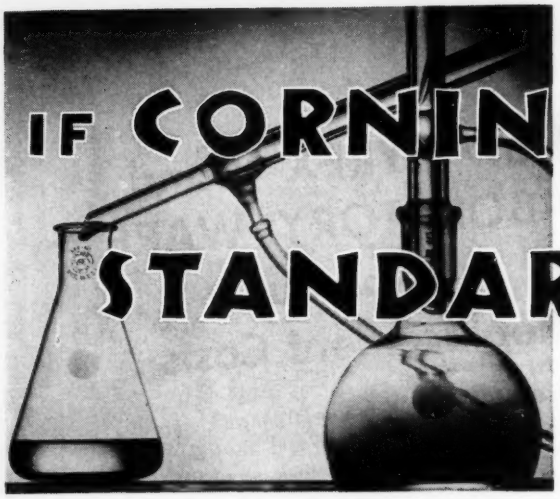
Four Week Delivery



TYPE AN-2012 ..... **$290.00**
200 gram capacity **1/20 mg. sensitivity**

AMERICAN BALANCE CORP.
408 POTTER AVE., NEW ROCHELLE, N.Y.


How PYREX Brand
LABORATORY WARE
Helps Cut
Replacement Costs
Tough, durable PYREX brand laboratory ware has the added resistance to thermal and physical shock that stands up under student knock-about use. And the extra long, dependable service that PYREX brand gives can mean substantial savings to you, especially in these days of rising costs. Accurate records kept by an Eastern College, for example, show that PYREX brand test tubes outlasted any other type 3½ times to 1.
Behind the outstanding advantages of PYREX brand laboratory ware is a scientific blending of physical and chemical characteristics . . . so carefully carried out that all the properties essential for economy, accuracy and durability are combined and maintained at their maximum value. See your laboratory dealer now about your future PYREX requirements.
PYREX
CORNING GLASS WORKS Corning, N.Y.
Corning means research in Glass
1851 • 100 YEARS OF MAKING GLASS BETTER AND MORE USEFUL • 1951



IF CORNING MAKES IT STANDARD HAS IT*

FOR *Fast* DELIVERY!

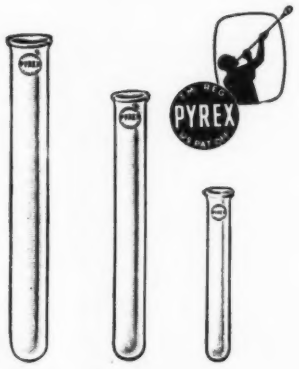
SAFETY -- ECONOMY -- CONVENIENCE

It will pay you to "Standardize" on "Pyrex Brand" Glassware

SAFE—"Pyrex Brand" Laboratory Glassware is mechanically stronger and less apt to break under ordinary usage. Its extremely low thermal expansion minimizes losses from thermal shock and permits heavy, rugged construction, increasing the resistance to mechanical breakage. The result is greater safety to laboratory workers.

ECONOMICAL—"Pyrex Brand" Laboratory Glassware is more economical because it lasts longer! The low alkali characteristics and the high chemical durability, combined with Corning's manufacturing skill and inspection control, produce a finished product unequalled in the world. It has been proven that savings of one-third on test tubes can be effected with "Pyrex" Brand!

CONVENIENT—"Pyrex Brand" Laboratory Glassware is available for an almost unlimited range of uses. You can be certain that you'll find just what you need in the "Pyrex" line.



#9550 TEST TUBES, with Lip, "Pyrex" Brand. Highly resistant to heat, will withstand repeated autoclaving. They are strongly made, well-annealed and are chemically stable.

O.D. mm	13	15	16	18	20	25	25
Length mm	100	125	150	150	150	150	200
Case Quantity	720	720	576	576	576	360	288
Each	.04	.0475	.0525	.06	.07	.115	.125
Per Case	25.92	30.78	27.22	31.10	36.29	37.26	32.40

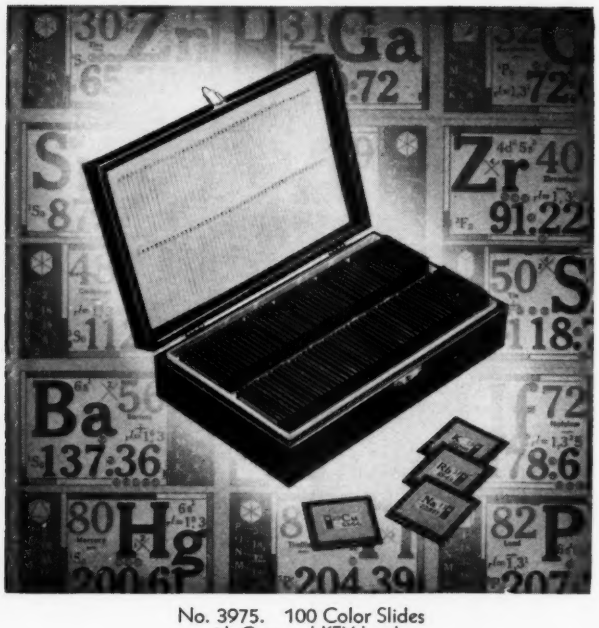
* EVERY PYREX (T.M. REG. PYREX PAT. OFF.) ITEM IN THE LABORATORY FIELD IS STOCKED *by*

STANDARD SCIENTIFIC SUPPLY CORP.
34 West 4th Street New York 12, N. Y.

Niels Bjerrum

(See page 433)

100 COLOR SLIDES OF THE ATOMS



No. 3975. 100 Color Slides with Case and KEY book

Now Available —made directly from the WELCH CHART OF THE ATOMS

- *98 Color Slides of the Elements*
- *1 Color Slide of the Complete CHART OF THE ATOMS*
- *1 Color Slide of the Key rectangle explaining data*

The slides are made directly from the Hubbard Chart of the Atoms and therefore include the most recent material brought up-to-date by Dr. William F. Meggers, of the National Bureau of Standards.

Includes the new elements

NEPTUNIUM	AMERICIUM	BERKELIUM
PLUTONIUM	CURIUM	CALIFORNIUM

This excellent set of ONE HUNDRED 2″ x 2″ COLOR SLIDES is ideal for lecture room study, discussion, or comparison of the structure and characteristics of the atoms. They are of particular value to the instructor who wishes to direct class discussion by specifically pointing out and explaining the data for each element, because in a projection of giant size the data is fully visible from any position in the lecture room. Full attention of the class may thus be focussed for study of any one element or family of elements, and students will understand the organization and function of the material assembled more quickly. The arrangement of symbols and the scheme of Color Representation present a complete picture of the atoms which is not available in any text.

WITH THIS SET YOU HAVE

COMPLETE FLEXIBILITY—The Groups of Elements best suited for your purposes CAN BE CONVENIENTLY AND QUICKLY ASSEMBLED. They are available for discussing almost any subject such as oxidation, reduction, crystal lattice, electrolysis, differentiation electrons, ionization potential, nuclear composition, isotopes, melting points, valence, Young's Modulus, etc.

The complete set of 100 Color, Glass-mounted Slides comes in an attractive, black leatherette case with fastener and hinged cover. (Sold only as a complete set.) No. 3975 Complete with 48-page Key—$75.00

W. M. WELCH SCIENTIFIC COMPANY

Established 1880

1515 SEDGWICK STREET, Dept. D, - CHICAGO 10, ILLINOIS, U. S. A.

Manufacturers of Scientific Instruments and Laboratory Apparatus

Editor's Outlook

EDUCATION seems always to be in the midst of a crisis—or even simultaneously in several. One of those in which it is involved just now does not—happily—particularly concern science education. But although the heat has been generated in the social and political areas there is no telling when the fever will spread to others. It came to a head in the recent "Pasadena incident," the details of which need not be recounted. A superintendent was brought in to reorganize and improve the school system. He proved too "progressive" for his constituency; the principal complaint was that his innovations ignored the rights of the home and prepared pupils for a life of social regimentation rather than one of intelligent individualism. Bloodhounds thought they detected a vague scent of communism. Public furor and the failure of a bond issue to implement the new program led to the superintendent's resignation. The wild debates brought out the clear issue: to what extent is the younger generation to be subject to the "educational experts"; what, if anything, shall the home and the rest of society have to say about educational policies, the curriculum, etc.?

This is not a new issue, by any means. The question is always being asked: "Who tells the teacher what to teach?" The school and the home are not always at peace, although society must of necessity charge the school with the responsibility for education of the child. This responsibility must be enforceable, but things can only go smoothly when there is complete trust between the two, home and school.

We in our branch of education are only lucky that we do not meet this difficulty in too direct a form. Parents are not apt to rush in to demand that the chemistry teacher emphasize the association of ions rather than the dissociation of salts (as maybe he ought!), but I can imagine some possible local heat over such a thing as the implication of atomic energy. Pressure on the chemistry curriculum does come from certain sources, to be sure. Most of us believe, however, that the efforts of such agencies as the A. C. S. Committee on Professional Training are well meant and helpful.

The record in other scientific fields hasn't been so good. Legislators have dictated the content of biology curricula, to shut the teacher up on the question of evolution, and have even attempted to define the exact value of the constant, pi.

But to come back to the beginning. The main question is of course general and important. What are the objectives of education and what are the respective stakes of society and the individual in it? The control of the administration of education is an attendant issue. The question is a hard one to resolve because it is one of the many battlegrounds of the contest between society and the individual. Until the outcome of that contest is clearer there will be no final solution in education.

Criticism from the outside often fails to appreciate the difference between education and propaganda. Education in this country is founded—thank God—upon the principle of complete freedom to see the truth and the whole truth, as nearly as we are able to discover it and present it. Facts are not suppressed because they are "not in the interest of the people." If a fact is antisocial, society will have to face up to it, just as an individual does when confronted with something detrimental to himself. The student has the right of freedom of inquiry; there are no beliefs which he must adopt ready-made because his teacher says so. This is as true of so-called "progressive" education as it is of "old-fashioned" and, allowing for the inability of the very young to reason on complex issues, is true at every level of the educational process.

The educational system in this country is public; it was founded by the people and is therefore responsible to us all. We could—I suppose—abolish it if we chose to do so; we have the right to do anything we want with it. But we should exercise this power of veto with the greatest caution, only if we are convinced that the principle upon which it was founded is being abrogated—the principle of freedom of inquiry. If we jump up to tamper with the machinery every time we think someone's thoughts are leading him off in the wrong direction, then there is no freedom of inquiry. A free society can only result from the association of people whose minds have been developed in an atmosphere of freedom.

Education is the biggest business going on in this country today, in point of money and personnel involved. Its administration is a job for professionals and is a challenge to the best brains and ability which the country can produce. If we have no confidence in the men in key executive positions it does no good to fume at the schools of education which are their training grounds. Rather, we must make this a more attractive and professionally respectable field, to increase the competition and get still better material.

AN INTRODUCTION TO RADIATION CHEMISTRY[1]

MILTON BURTON
University of Notre Dame, Notre Dame, Indiana

RADIATION chemistry is the chemistry of the effects of high-energy particles and radiations, including both radioactive emanations and the energetic products of high-voltage machines and nuclear reactors.

Occasionally, during our half-century of knowledge of radioactivity, the study of such chemical effects has been called radiochemistry. However, that usage has been avoided by some authors because the same term was also more generally applied to the chemistry of the radioelements including their chemical properties and reactions (*36*). Lind (*44*) and Mund (*50*) both omitted the word radiochemistry from the titles of the major books so far written in this field, although in the books themselves they employed it in the sense that we now use radiation chemistry. As a matter of practical convenience, avoidance of ambiguity is desirable in identification of a field. During the years of World War II the term "radiochemistry" was used throughout the so-called Metallurgical Project[2] in its more general sense. The term "radiation chemistry" was adopted for the more restricted field here discussed as a matter of sheer necessity. Had a better term been suggested, it would have received a hearty welcome.

EARLY DAYS

Certain micas, as well as other minerals, show tiny specks which may be sectioned and photographed through a microscope. Such microphotographs show series of concentric rings (called haloes) and indicate that each speck is really a series of concentric spherical shells, the record of the presence in some by-gone time of an even tinier speck of long-extinct alpha-particle emitter (*40*). Each shell corresponds to the range of a particular particle; study of such ranges has been used to distinguish uranium and thorium haloes (*58*). A curious aspect of the results is that some of the ranges did not correspond to any of the radioactive isotopes known at the time of the observations. Perhaps, the production of new alpha-particle emitters in the atomic piles may serve to clear up some of these mysteries. Nature was producing these, and other radiation chemical effects long before man became interested.

In 1895, Roentgen reported that exposure of a covered photographic plate to invisible, highly penetrating rays (*i. e.*, X-rays), which he had sought and discovered, resulted in production of a developable image (*56*). That same year, on learning of Roentgen's discovery, Becquerel set out to examine a large variety of fluorescent substances with the purpose of discovering possible natural sources of penetrating rays. In February of 1896 he reported[3] (*2*) that rays from the uranium mineral pitchblende, just like X-rays, also fogged a covered photographic plate. In 1898 the Curies were able to report isolation of polonium and radium, major constituents of the mineral (*20*).

Although studies in radiation chemistry preceded the beginnings of radiochemistry, developments in the latter field have from the very beginning promoted interest in the older one. As a matter of fact, Becquerel was not aware when he made his first report that the radiation responsible for the so-called "Becquerel effect" was of nuclear, or even atomic, origin. Initially, he was of the opinion that only a limited number of fluorescent salts of uranium caused it, for at the time he believed a connection to exist between fluorescence and X-rays. Later, he recognized that *all* salts of uranium produced the same effect and correctly interpreted the source of his active radiations.

Early workers in the field of radioactivity were literally plagued with the phenomena of radiation chemistry. Radiations from samples dissolved in aqueous solution decomposed the water according to two overall reactions:[4]

$$2H_2O \xrightarrow{\sim\sim} 2H_2 + O_2$$
$$2H_2O \xrightarrow{\sim\sim} H_2O_2 + H_2$$

The product "electrolytic gas" (somewhat rich in hydrogen) escaping from the solution could carry with it, as a spray, some of the radioactive content. Such material, escaped into the air, must certainly have been a source of confusion, as well as of danger, to the early workers. Resultant radioactive contamination of their instruments and of the air they breathed was neither convenient nor healthful. If an effort were made to avoid such contamination by sealing the vessel, the phenomenon of spray might appear with increased intensity when the vessel was opened. The obvious solution to the problem was to store only dry samples in sealed vessels (for radon also had to be guarded against). Even then, with more active samples, there can be trouble. Not only does the sample itself become dis-

[1] A contribution from the Radiation Chemistry Project of the University of Notre Dame operated under Atomic Energy Commission Contract AT(11-1)-38.

[2] "Metallurgical Project" was the code name by which the Chicago and associated branches of the activities of the Atomic Energy Project was known during the days of the "Manhattan District" of the Army Engineer Corps.

[3] See the excellent review of these experiments in ref. (*30*), chapter I.

[4] The symbol $\xrightarrow{\sim\sim}$ in radiation chemistry can be read "under high-energy irradiation gives."

colored but the radioactivity causes, first, coloration and then weakening of the glass or quartz vessels. Microscopic cracks appear. If, inadvertently, the radioactive salt is only partially dried, the pressure of electrolytic gas built up in the vessel may be sufficient to rupture it and produce even more disagreeable results (*4*).

Hiroshima, Nagasaki, and Bikini have educated nearly every literate layman to the fact that the radiations from radioactive materials are dangerous, but this fact was not at all apparent to the early workers. One can pick up a radioactive sample with absolutely no sensation of discomfort. A day or so later, depending on the strength of the sample, the burn may be quite dark and destruction of tissue may be deep and extensive. Such exposures in many cases led to cancer and were ultimately fatal.[5] Balanced against this sensitivity of normal tissue is the fortunate fact that malignant tissue is even more susceptible. Thus, it was found that carcinomas can be destroyed by exposure to the rays from radon needles; *i. e.*, tiny sealed glass tubes which contain the short-lived radioactive emanations from radium.[6]

As a result of this variety of disagreeable and, more rarely, agreeable experiences a natural curiosity developed regarding the causes of the effects observed. At first, the studies were made principally in the laboratories of the Curies but later a number of other investigators including Duane and Wendt, Kailan, Przibram, Mund (*50*), and especially Lind and his co-workers (*44*) became interested in the chemical effects of rays from radium. In the period up to 1922 the literature was sufficient to warrant Lind's extensive review in the first edition of his book; by 1929 a second edition was required (*44*).

THE PHOTOCHEMICAL ANALOGUE

The two fundamental principles of photochemistry are the Grotthus-Draper law (the amount of chemical action induced by light is proportional to the amount of light absorbed) and the Stark-Einstein law of photochemical equivalence (the number of primary processes produced is equal to the number of photons absorbed). The first principle was already well known when radiation chemistry came into being. The notion of transfer of energy from the radioactive emanation to the chemically affected material might consequently have been taken as axiomatic. The nature of the process involved was, however, not quite so apparent for it was known that similar results were obtained not only with high-energy particles such as alphas and betas but also with gamma rays.

The clue to the primary physical phenomenon was first given by Duane who showed that an alpha particle simultaneously loses its ability to ionize a gas, to produce luminescence, and to produce a chemical effect (*24*). Even until 1910 it was thought by some that the chemical effect of radioactive materials was catalytic; this notion was dissipated by Usher (*67*) who showed that both decomposition of ammonia and its formation from nitrogen in the presence of radon were attributable to alpha rays.

Although it was W. H. Bragg (*6*) who first calculated that the number of molecules of water decomposed by a radon sample corresponded approximately to the number of ions that sample would produce in air, it was Mme. Curie (*21*) who first treated this correspondence as something more than an accidental relationship. Le Blanc[7] also was aware, about the same time, of the significance of this relationship. Lind was unquestionably the first who began to exploit this idea. Beginning in 1911 he published many papers in which he compared the chemical yield with the number of ion-pairs initially produced by the radiation.[8] A particularly interesting study was one in which he and his co-workers showed that for the reaction

$$H_2 + Cl_2 \rightarrow 2\,HCl$$

performed under similar conditions the photochemical quantum yield (molecules converted per photon absorbed) and the radiation chemistry ion-pair yield (molecules converted per ion-pair produced) were approximately the same, *i. e.*, of the order of 10^6 under most favorable conditions (*54*). From such tedious efforts it thus seemed to be established that to the role of the photon in photochemistry there corresponded that of the ion-pair in radiation chemistry. Corresponding to quantum yield (γ, Φ, etc.) in photochemistry there came into extensive use the M/N ratio, now called ion-pair yield, of radiation chemistry.

Unfortunately, the analogy between quantum yield and ion-pair yield has frequently been pressed too hard. Lind himself was the first to indicate that an exact correspondence was lacking and that, in many cases, those yields were distinctly different, frequently by a factor of two or more under similar conditions. To explain these observations, and for a variety of other reasons, it was suggested by Lind that an essential difference between photochemistry and radiation chemistry lay in formation in the latter of ions around which molecules could cluster and there react. This view is not now generally accepted (*57*).

BASIS OF PRESENT VIEW

The present view of the fundamental processes of radiation chemistry was most clearly formulated by Eyring, Hirschfelder, and Taylor (*27*) (EHT) who pointed out a twofold nature of primary physical effects produced in radiation chemistry. A fact generally appreciated for a great many years is that high-energy

[5] For a poignant account of the life and death of two of the early American pioneers one should read an article by A. Silverman (*62*).

[6] Recently, a group collaborating with Dr. Hahn at Meharry Medical College in Nashville, Tennessee, has pressed this technique to its ultimate extent. They inject colloidal solutions of short-lived, artificially produced radiogold into cancerous tissue with encouraging results (*34*).

[7] See ref. (*36*), p. 85.

[8] These experiments began with studies of the production of ozone (*45*).

radiations and particles do not produce ionization on every impact. Here, we use impact in the sense of an interaction during which energy may be transferred. It is possible that the energy transferred is insufficient to cause ionization. In such case, the energy appears in the particle "hit" as electronic excitation. The excited molecule thus produced does not differ from the excited molecule of photochemistry. Like the latter it may enter into a variety of chemical and physical processes. The contribution of such excited molecules was neglected prior to the suggestion of Eyring, Hirschfelder, and Taylor.

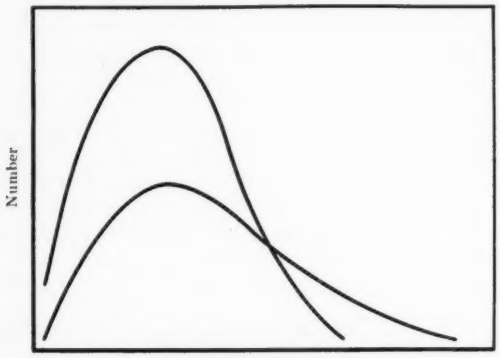


Figure 1. Typical β-Ray Spectra

Furthermore, another aspect of the primary process was presented in a fresh way by Eyring, Hirschfelder, and Taylor. Prior to them, it had been generally assumed that the ions entered into reactions as ions. They suggested that, for the most part, before any chemical process could occur, the ion would be discharged with production of an excited molecule. Such excited molecules then enter into ensuant reactions just as if they had been produced photochemically. Details of this mechanism are discussed later in this article. At this point we may merely say that this development of the theory of radiation chemistry indicated existence of a closer correspondence to photochemistry than had previously been suspected. In terms of this correspondence, the essential nature of the differences, which we will now discuss, becomes more obvious and more readily susceptible to explanation and to prediction.

RADIATION PARTICLES, SOURCES, EMPLOYMENT, AND PRIMARY EFFECTS

In radiation chemistry, the bearers of energy are highly energetic photons and particles. Since they are of a type which are susceptible to the wave treatment of quantum mechanics it will be convenient to speak of both types either as particles or as radiations; only exceptionally will their corpuscular nature affect our considerations.

The particles of radiation chemistry are the emissions of radioactive decay (alpha, beta, and gamma rays, neutrons, and atom and fission recoils) as well as their artificially produced analogues (*e. g.*, highly accelerated protons, deuterons, helium nuclei, electrons, X-rays, etc.). For the sake of clarification, it is desirable to point out that there is some difference between beta rays (*i. e.*, electrons produced by nuclear decay) and energetic electrons produced in an electron accelerator. Distribution of energies in typical beta-ray spectra is shown in Figure 1. The spectrum reflects the history of production of the beta rays; the concept of the neutrino emitted from a nucleus simultaneously with the beta particle was developed in part to account for this wide distribution of energies (*3*). In contrast, electrons produced in an electrical accelerating machine are practically monoenergetic. The "line width" of a 1-mv. electron beam so produced need not exceed 50 k. e. v., *i. e.*, 2 per cent of the total energy.[9] On the other hand, the situation regarding gamma and X-rays (both of which are photons) is somewhat the reverse of that regarding the electrons. Gamma rays, emitted from the nuclei, are practically monoenergetic; such photons have very precise energy determined by the upper and lower states between which the accompanying nuclear transitions occur. X-rays are extranuclear in their origin. They are produced directly or indirectly in deceleration of electrons, which may themselves be monoenergetic. However, such a great variety of electronic states is usually involved that the X-rays emitted cover a wide variety of energies. The maximum energy of the X-rays is, of course, determined by the maximum energy of the electrons involved. X-rays produced in high-voltage machines (order of 1 mv. or greater) tend to be concentrated in the "forward direction" of the electrons (*52*).

Sources. The energetic particles of radiation chemistry are produced, as we have seen, either artificially or by radioactive decay. Table 1 lists various convenient sources together with some rough indication of the energy[10] of the radiation produced. Historically, the radioactive nuclides[11] are the most significant for, apart from the original discovery by Roentgen of the photographic effect of his X-rays, nearly all the early studies were on the effects induced by radioactive elements. For the most part, also, the effects studied were those of alpha rays. In experiments on gases particularly, admixture of radon served, and still serves, to give a convenient source of alpha particles of known energy

[9] The designation mv. (or kv.) refers to the field through which a particle has been accelerated, the designation m. e. v. (or k. e. v.) to the energy which a particle has. Thus, a 2-mv. electron has been accelerated by a two-million-volt field and has 2 m. e. v., or two million electron volts, energy. An alpha particle (charge +2) accelerated by such a field has 4 m. e. v. energy. For convenient comparison 1 e. v. per electron is equivalent to 23,063 cal. mol^{-1}.

[10] We employ the term "energy" to give us information about the single particle *e. g.*, a photon or an alpha particle. Any convenient unit such as a 1-m.e.v. particle or a 1.0 Å. wave can be used. "Intensity," on the other hand, is a measure both of the energy and of the number of particles per unit time and also per unit area or pure unit volume.

[11] We follow the terminology of Kohman (*41*), who defines a nuclide as "a species of atom characterized by the number of protons and neutrons in its nucleus."

and intensity. Increased availability of polonium 210 (half-life 140 days for 5.3-m. e. v. alpha particles) will probably result in more experiments where the alpha particles originate at a surface or, in some cases, in suitable solution. When a surface source is employed, care must be taken to correct for errors introduced by energy loss within the surface layer.

Radioactive nuclides are also employed as sources of betas and gammas in radiation chemistry but until recently, the attainable intensity level was usually too low. Consequently, such use was not particularly desirable. However, there are special studies, particularly in radiobiology, where such technique is preferable. The increased availability of radionuclides from the Atomic Energy Commission at Oak Ridge will promote experiments in which it is desirable to include the source of radiation within the material studied. An interesting example of this type was provided by Ghormley and Allen (*32*) who have used tritium oxide in pure water as a source of slow-energy electrons from the reaction $H^3 \rightarrow He^3 + \beta$. For other purposes, a source which continues to produce radiation at uninterrupted rate over a long period of time without attention is most necessary. A typical source of the latter type is Co^{60} (half-life 5.3 y., 1.1- and 1.3-m. e. v. gammas) now obtainable in amounts of the order of hundreds of curies.

The difficulties in the past inherent in use of low-intensity radioactive nuclides as gamma-ray sources were avoided to some extent by employment of the X-ray tube in radiation chemistry. This technique proved particularly fruitful in the hands of Fricke and his co-workers who studied the decomposition and oxidation of a variety of organic compounds in the pure state and in aqueous solution (*29*). Difficulties resultant from the low intensity of usual beta sources were met in an equally direct manner. Schoepfle and Fellows (*59*), for example, have used cathode rays at about 170 kv. and 300 μa. coming through a thin window as a convenient source of electrons. The study of chemical reactions in electrical discharges (*33*) may also be considered as one way of circumventing the problem of low intensity but, as a matter of fact, there is sound experimental and theoretical reason for consideration of this latter field separately from the chemical phenomena produced by the much more energetic particles of radiation chemistry.

TABLE 1
Radiations Employed in Radiation Chemistry and Their Sources

Source	*Radiation particle*	*Typical maximum energy*	*Energy width*
X-ray tube	X-ray	600 k. e. v.	Broad
Van de Graaff generator	Electron	6 m. e. v.	50 kv.
	X-ray	6 m. e. v.	Broad
Cyclotron	Proton	Dependent on instrument up to 32 m. e. v.; see discussion	Sharp
	Deuteron		
	"Alpha"		
	Neutron		
Betatron	Electron	>20 m. e. v.	Broad
	X-ray		
Nuclear reactor ("pile")	X-ray	Order of 1 m. e. v.	Broad
	Neutron	Order of 1 m. e. v.	Broad
	Fission recoils	Order of 100 m. e. v.	Broad
	Alpha particle, triton, etc.	Dependent on technique	Dependent on technique
Natural or artificial radionuclide	Gamma	Dependent on nuclide	Sharp
	Betas		Broad
	Alpha		Sharp
	Atom recoil		Broad

TABLE 2
Some Comparative Costs of Radiation Sources (Including Labor, Installation, etc.)

Ra	$20,000 per gram
2 curies Co(60)	$43 min. plus $50 per curie plus handling and shipping plus cost of shield[a]
Cyclotron	$100,000 min.
Van de Graaff generator	$100,000
Atomic energy pile	?

[a] These figures are from Catalogue and Price List No. 3, July, 1949, of the Isotopes Division of the United States Atomic Energy Commission, Oak Ridge, Tennessee. They are subject to revision—usually in a downward direction.

The problem of an adequate source of electrons and X-rays was finally solved by employment of the Van de Graaff generator during the war years (*9*). Its "sharp-line" electron spectrum is a factor of practical convenience. Perhaps, the most interesting features of the instrument are relative ease of operation, a minimum of maintenance difficulties for such a high-voltage instrument, relatively low installation costs, and the fact that it is now commercially available. Instruments for operation at the high voltage indicated in Table 1 must still be built as a separate project but a 2-mv. instrument can be purchased without too much difficulty.[12]

Not all instruments shown in Table 1 are equally useful for the radiation chemist. During the war years all those instruments were used but, even at that time, the betatron was not a convenient source. The radiations from the betatron are scattered over a wide range energetically and geometrically. Thus far, it produces X-rays and electrons of the highest attainable energies. However, the chemical effects of particles of such high energy are not of immediate theoretical interest and the compensating disadvantages (in exposure technique, monitoring of exposure, mixture of radiations and energies) in its employment decrease its present applicability.

The cyclotron was employed as a source of radiation in radiation chemistry for the first time during the years of World War II. At that time, on a non-secret enterprise beginning in 1943, a group at Massachusetts Institute of Technology employed deuterons from a cyclotron in studies of the radiation chemistry of fatty acids (*7*). A little earlier, the Radiation Chemistry Sections

[12] A 2-mv. Van de Graaff generator constructed by the High Voltage Engineering Corporation of Cambridge, Massachusetts, is installed at the Radiation Chemistry Project at the University of Notre Dame. The total cost of the installation in a specially built concrete structure including provision of necessary remote-control laboratory and services, was less than $100,000.

of the Metallurgical Project had started to use all available cyclotrons as deuteron sources for a variety of purposes (*9*). Neither group was aware of the activities of the other. Any cyclotron with an external beam can be employed irrespective of the nature of the particles it produces. Furthermore, it is possible also to make probe exposures with an internal target, when the reactant is a solid or when the exposed material can be conveniently enclosed in a capsule with very light walls.

As we shall see, there are cases in which chemical effects of neutrons can be simulated by employment of deuterons (or other heavy charged particles) but there are certain studies in which neutrons alone are properly employed in the first instance. For such experiments, the cyclotron has almost unique significance. Deuterons from an external beam strike a beryllium target and produce high-energy neutrons by the reaction Be^9 $(d, n)B^{10}$; *i. e.*,

$$_4Be^9 + {}_1H^2 \rightarrow {}_5B^{10} + {}_0n^1$$

The maximum energy of the neutrons exceeds that of the incident deuteron beam by about 4 m. e. v. A lithium target gives much higher energy neutrons but the neutron yield is only about one-third (*30*).

Of course the atomic energy "pile" or nuclear reactor is the best source of neutrons. However, it is not always available and, when it is, the neutrons are mixed with other radiation, *e. g.*, gamma. In such work possible contributory effects of these incidental radiations must be considered. On the other hand, when chemical effects of fission recoils are to be studied only a pile appears as a satisfactory tool. However, as matters now stand, such investigations are of major interest only to to investigators concerned directly with pile phenomena and pile development. It is unlikely that outside interest in such matters will be encouraged in the present state of world affairs.

Techniques. The techniques of radiation chemistry are far from frozen. Types of target vessels employed far exceed the number of investigators and are almost as numerous as the number of diverse experiments. General factors taken into consideration include window thickness, vessel material, grounding, current measurement devices, cooling and temperature control, fluid circulation, distribution of energy absorption, product collection, measurement, and analysis. Except for X-ray work, it is important to reduce window thickness to a minimum and to make appropriate correction for energy absorption in such windows. In deuteron bombardment of an aqueous solution it is commonly found that the deuteron penetration is less than 0.5 mm. For example, in such experiments a thickness of aluminum window exceeding 1 mil cannot be tolerated. The vessel material must, of course, be chosen so as not to interact with the reactant under the specially stringent conditions of radiation chemistry. However, another factor must be just as carefully considered in studies of the effects of deuterons (or other heavy particles) from a cyclotron. The vessel material and vessel support must yield a minimum of hazardous radioactive product under conditions of irradiation. Unless gammas are responsible for such possible hazards sufficient protection can usually be achieved by coating the vessel and its support with a thin coating of a suitable metal.

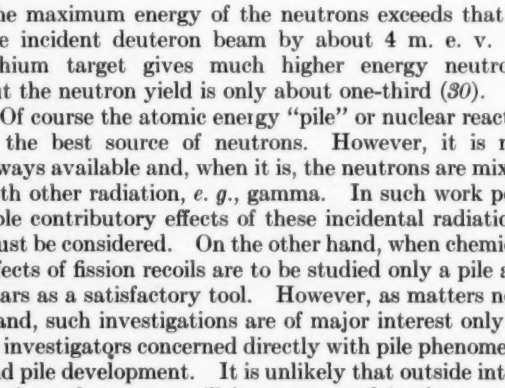


Figure 2. Ionization Density as a Function of Distance Traversed for a Uniform Beam of Heavy Charged Particles (Schematic)

When the reaction vessel is not grounded much of the incident charged-particle radiation can be reflected from its surface without entry into the reactant. In such experiments false conclusions can be reached regarding resistance of the reactant to radiolysis (*i. e.*, decomposition of reactant by high-energy radiation). Indeed, precaution against such an effect must be exercised even when the vessel is deliberately grounded through a current-measurement device. It has been found that the ground wire must be brought into the reaction zone very close to the cell window to prevent back reflection of the charged-particle beam. Surely precautions to ensure collection and dissipation of the entire beam in the reaction cell cannot be over-emphasized. Current measurement devices should offer minimum resistance to ground and should be rapidly responsive to current variation. The Leeds and Northrup Speedomax recorder has proved particularly effective.

In typical experiments employing machine sources of radiation, energy is frequently dissipated in the reactant at a rate of 1 to 10 watts $cc.^{-1}$ Unless external cooling is employed or the total volume of available reactant in a circulating system far exceeds the exposed volume, the temperature would rise at a rate which might, at the very least, preclude simple interpretation of the results. When an external cooling or circulating device is employed, the device itself must be isolated from the ground, so that there can be no loss of current through it. Oil cooling has been used with cyclotron irradiation but a convenient and simple arrangement is to flow the coolant dropwise onto and off the reaction cell.

A characteristic difficulty in radiation chemistry (as well as in photochemistry) is the anisotropic distribution of absorbed energy. This anisotropy is both microscopic and macroscopic. It results from the character of the charged-particle track. The latter feature is discussed more appropriately in later sections; here we

consider only the grosser aspects of anisotropy. Consider first charged-particle effects. For such particles, the less their velocity the greater their interaction with matter. Thus, we find that a particle which has already lost most of its energy loses the balance at an increasing rate. Figure 2 shows a characteristic relationship between the intensity of ionization produced in a gas by a beam of charged particles of initially uniform energy and the distance traversed. Near the end of the path the ionization density is a maximum. This is the common type of ionization curve obtained in alpha-ray studies. It is not characteristic of beta rays because the beta rays themselves are not initially of uniform energy. It is not quite characteristic even of ionization produced by electrons from a Van de Graaff generator even though they are of initially uniform energy. Scattering and secondary X-rays produce an effect best shown by Figure 3, which shows pages from a pad exposed to the 2-mv. beam of the Radiation Chemistry Project Van de Graaff generator. We may summarize the difficulty by the statement that even with X- or gamma rays isotropic energy absorption is not obtained. At best, if the ordinary Beer-Lambert law were followed,

$$I = I_0 e^{-\alpha c d}$$

we would have exponential decrease of energy absorption density. In fact, the absorption law is complicated by Compton scattering and energy degradation of the beam. The best arrangement is to work with a relatively small thickness of absorbent; under such conditions, with a uniform gamma beam almost isotropic distribution of energy absorption obtains. The most important points to remember are that anisotropic distribution is the rule and that this distribution must be considered in any interpretation of results.

The problems of product collection, measurement, and analysis are not peculiar to radiation chemistry. Neither is the possible entry of products into secondary reactions. What is peculiar to radiation chemistry is the fact that reactants and products are *a priori* potentially equally susceptible to high-energy radiation; indeed, in certain cases (*e. g.*, when the reactants are aromatic) the products may be far more susceptible. This fact emphasizes the desirability of limiting the studies, for ease of interpretation, to relatively short times of exposure. An interesting technique, usable for such short times of exposure, employed by W. H. Hamill and R. R. Williams and their co-workers of the Radiation Chemistry Project involves the inclusion in an exposed material of a trace of radioactive material such as iodine. The iodine is present in such low concentration that most of the effect of the radiation is in the ambient fluid. Any free radicals formed therein, however, react with the iodine and produce trace quantities of radioactive iodides. The latter are identified by subsequent mixing of the reactant with a variety of iodides which are then separated by distillation or other convenient means. The location of the radioactivity in the separated fractions identifies the products formed (*69*).

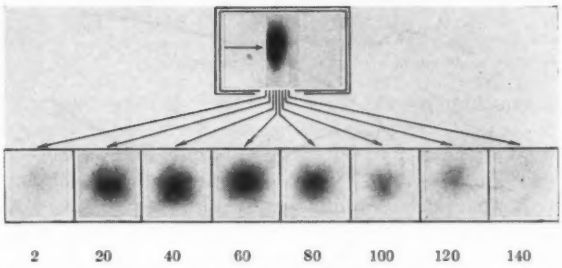


Figure 3. Photographs of a Paper Pad Exposed to a 2-m. e. v. Beam of Electrons about 1 cm. in Diameter at the Target

These pictures show also secondary effects of charring around the darker irradiation spots. At the top is a cross section through the spot. The arrow shows the direction of irradiation. The numbers are those of the sheets in the pad.

Primary Effects. The primary physical effects of radiation are summarized briefly in Table 3. Both X- and gamma rays eject electrons from matter with which they interact and it is the interaction of these electrons with the material in which they are produced which is responsible for the overwhelming portion of the chemical effects. The single atom affected by the X- or gamma ray in the first instance makes an undetectable contribution to the total chemical change.

TABLE 3
Primary Effects of Radiation

Radiation	*Effect*
X- or γ rays	Electron emission { photoelectron; Compton electron; pair production
Neutrons	Knocking-out of nucleus Ionization Excitation
Charged particles	Knocking-out of nucleus Ionization Excitation

Neutrons interact exclusively with the nucleus of the atom in a kinetic energy transfer process. The average amount of energy transferred in such a process is given by the relation

$$-\frac{\Delta E}{E} = \frac{2A}{(A+1)^2}$$

where E is the kinetic energy of the neutron and A is the mass number of the the knocked-on nucleus. It may be seen from Figure 4, however, that not all the energy transferred is imparted as kinetic energy of the nucleus. Consider that the nucleus is ejected from its original position with a velocity v_n (the neutron is *not* shown in the picture). According to the classical Bohr model, which is adequate for our present purpose, a number of electrons are circulating in eliptical orbits around the nuclei with average velocities at any instant which can be represented as v_1, v_2, etc. Consider two electrons, one in which $v_1 < v_n$, the second in which $v_2 > v_n$. As a result of the neutron impact, the electron with $v_1 < v_n$ will be left behind the ejected nucleus; the atom is said to be ionized. On the other hand, the

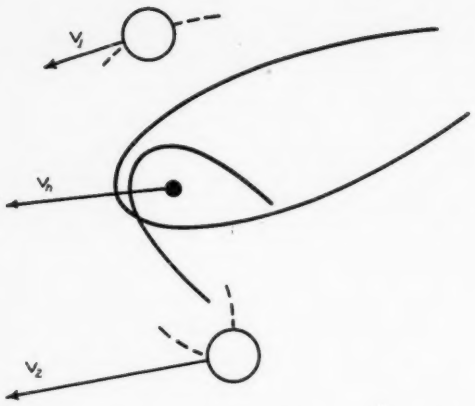


Figure 4. Ionization and Excitation by Neutron Impact

electron with $v_2 > v_n$ will not be left behind; it may, however, be displaced with respect to the nucleus into a new characteristic orbit; the atom is said to be excited. The nucleus ejected in this fashion may have energies of the order of hundreds of k. e. v. and can in its turn eject other atoms from their normal positions in a sort of avalanche effect. Thus, one neutron may be responsible for the displacement of a large number of atoms; indeed, in the case of water, for example, protons ejected by initial neutron impacts are responsible for practically all the observable chemical effects obtained by neutron irradiation.

Charged particles interact for the most part with the electronic cloud around the molecule. The interaction is directly related to the charge on the particle and inversely related to its velocity and the distance of closest approach. The less the velocity (*i. e.*, the longer the charged particle remains in the vicinity of the molecule) the greater the distance at which it can interact; we say that the cross section for energy transfer is greater for lower velocity particles. If we compare, for example, a proton and an electron of equal kinetic energies, it follows from the relationship

$$K.\,E. = {}^1/_2\,Mv^2$$

that the velocity of the electron is about 43 times the velocity of the proton. Every molecule which the charged particle passes or encounters presents a much greater target to a proton than it does to an electron of equal energy and the probability of energy transfer to that molecule is correspondingly increased. The energy is transferred in the form of a displacement of the electrons in the electronic cloud. A sufficient displacement means that an electron is no more associated with the parent molecule than with any other in the medium. The molecule is ionized. Any displacement of smaller magnitude can correspond to an excitation. The density of ionization and excitation along a heavy particle track is much greater than along an electron track (*cf.* cloud-chamber photographs). A characteristic average distance between successive ionized molecules may be 5 to 10 molecules along a heavy-particle track, 100 to 500 along an electron track.

Figures like the foregoing apply only to energetic particles. Since the ionization density increases as the velocity decreases, it will attain a maximum (see Figure 2) just before the end of the path. Thus, low-energy electrons (*i. e.*, electrons of low velocity) should not behave sensibly differently in production of radiation chemical effects than do more energetic heavy particles. Ghormley and Allen (*32*) have made use of precisely this fact in the study of the effect of 5.6-k. e. v. betas from tritium on the radiolysis of water.

For more massive charged particles, such as fission recoils or atom recoils from radioactive processes, the ionization densities along the tracks may become even greater than indicated for such particles as protons, deuterons, and alphas. These effects are reflected in a special field of hot-atom processes in radiation chemistry: *i. e.*, those chemical processes initiated by radioactive recoils. Table 4 is according to a calculation by Davies (*25*). Apparently a typical beta emission does not always impart sufficient energy to the nuclear residue even to rupture the compound with which it is associated. On the other hand, it would seem that such rupture almost always occurs in typical alpha-emission processes and that the recoil atom may produce chemical effects in the support medium. However, the energy of the recoil is so much lower than that of the associated alpha that practically all the observed chemical effects are attributable to the latter.

TABLE 4

Recoil Energies and Velocities (According to Edwards and Davies (*25*))

Process	E_r	*Typical* E_r, *m. e. v.*	*Typical* M_r	*Typical* E_r, *e. v.*	*Typical* v_r, *cm. sec.*$^{-1}$
$-\alpha$	$4E_\alpha/M_r$	3	200	6×10^4	2.4×10^{8}
$-\beta$	$E_\beta/1800\,M_r$	1	100	5	3.1×10^{8}
$(+n), -\gamma$	$5.3 \times 10^{-10}\,E_\gamma^2/M_r$	5	100	130	1.6×10^{9}

E is energy; M is mass in atomic mass units; subscripts p and r refer to the projectile particle and recoil atom, respectively; v is velocity.

[a] Neglecting slight relativity correction.

The situation is somewhat different for the (n, γ) process; *i. e.*, the absorption of a neutron accompanied or succeeded by gamma emission. The emitted gamma generally penetrates a region far from its source and is without effect near it. On the other hand, the atom recoil frequently may have sufficient energy to break all its bonds and even (in some cases) to raise the atom to an unusually high ionized state. Furthermore, dense ionization along the atom track may produce characteristic chemical reactions which leave the radioactive atom in a different chemical state from its nonradioactive parent. It is this chemical phenomenon which is employed in the Szilard-Chalmers separation technique for obtaining high specific activity (*66*); for example, if potassium permanganate solution is exposed to slow

neutrons, product radioactive Mn^{56} may be filtered out of the solution as MnO_2 in high specific activity by an ordinary filter paper. In other cases where the technique is applicable more involved separations may be required but the principle is essentially the same. This particular branch of radiation chemistry has sufficient difference of character that it is usually considered separately in the field of hot-atom chemistry (*25*).

THEORY AND ILLUSTRATIONS

Ionization potentials are in the range 9 to 15 e. v. for most atoms and molecules, although those of the rare gases run somewhat higher. On the other hand, when high-energy radiation acts on a gas and the ion products are collected at a voltage sufficiently high to sweep out all the positive ions and negative ions or electrons (*i. e.*, ion-pairs) before their recombination and neutralization, it is found that approximately 25 to 32 e. v. of energy are expended per ion pair produced. The explanation is that the energy in excess of that required to produce ions is dissipated in electronic excitation processes. This interpretation has led to the general statement that in radiation chemistry approximately half the energy goes into ionization and half into excitation processes. Since the lowest electronic excitation potential is in general three-quarters or less of the ionization potential, it follows that the number of excited molecules exceeds 1.3 times the number of ion pairs and that the contribution of excited molecules to the phenomena of radiation chemistry must not be neglected.

The Eyring-Hirschfelder-Taylor Theory. Although these facts were long appreciated (*cf.* Lind (*44*)), their implications for radiation chemistry were first explicitly considered by Eyring, Hirschfelder, and Taylor (*27*) in 1936, who took into account the chemical contribution of excited molecules much as if they had been produced photochemically. However, this excited molecule effect is only one aspect of radiation chemistry. The behavior of excited molecules primarily produced by the high-energy radiation is in general understood from our knowledge of photochemistry. Two features, however, distinguish radiation chemistry from photochemistry. In photochemistry only certain substances may be affected by light of a particular wave length. All substances, and indeed all parts of any molecule, are susceptible to the effect of high-energy radiation. Furthermore, primary ionization characteristic of radiation chemistry produces chemical effects essentially different from those produced in photochemical processes.

The present point of view derives essentially from the work of Eyring, Hirschfelder, and Taylor (*27*) and has been summarized in a number of papers by Burton (*9, 10, 11*) and by Magee and Burton (*46, 47*). We consider particularly the ionization processes and the consequences thereof, noting in reserve at all times that the chemical consequences of primary excitation must not be neglected. The major reactions may be indicated in simple form as follows.

$$A \longrightarrow A^+ + e \qquad \text{I}$$

$$A^+ + e \rightarrow A^* \qquad \text{II}$$

$$A^* \begin{cases} \nearrow \text{Rupture into radicals} & \text{IIIa} \\ \searrow \text{Rearrangement into ultimate molecules} & \text{IIIb} \end{cases}$$

This presentation involves a gross over-simplification. Each step has manifest complexities.

Some Complications. The ionization step I represents only one of the ionization processes to which a molecule A is susceptible. In more elaborate detail, we may write

$$A \longrightarrow A^+ + e \qquad \text{I-1}$$

$$A \longrightarrow A^{+\prime} + e \qquad \text{I-2}$$

$$A \longrightarrow B^+ + C + e \qquad \text{I-3}$$

and note also the possibility

$$A^{+\prime} \rightarrow D^+ + E \qquad \text{I-4}$$

Reaction I-1 is the single process by which the molecule loses an electron with minimum energy input to produce an ion without excitation. In the old classical sense any electron in the molecule could be removed in the ionization process so that an average charge may be effectively localized in any one of many different groups. We say that "any part of the molecule may be ionized." We might also say that the molecule ion can be produced in a *variety* of different (excited) states, both stable and unstable, as shown by step I-2. Step I-3 is one in which the ionization process involves a state which decomposes via bond rupture within one vibration period into two particles one of which is a radical (or atom) and the other a radical (or atom) ion. An energy relationship consonant with step I-3 is shown in Figure 5. In any single complicated molecule, B and C

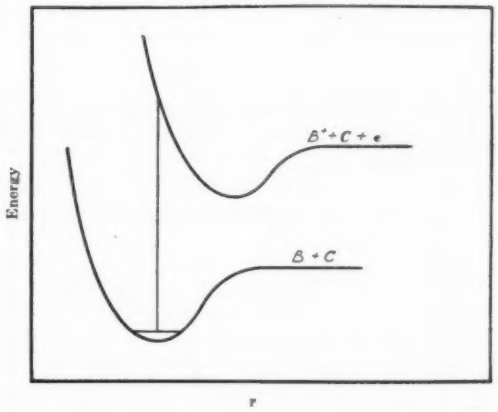


Figure 5. Ionization Accompanied by Rupture

The molecule A is shown as two radicals B and C joined by a single bond. The parameter r is the bond length.

may represent a variety of radicals, so that step I-3 also represents a variety of possible processes and suggests a variety of possible primary chemical products. The diversity of ions shown in a mass spectrometer record of a single molecular species is in part the result

of processes like I-3, where the effective "radiation" is really the stream of electrons from the filament of the spectrometer. However, not all the ions formed in a mass spectrometer are producible by simple rupture processes. Langer (*42*) notes that the masses 29, 43, 57, and 71 represent alkyl radicals repeatedly observed in the mass spectra of a number of hydrocarbons which could not produce them without rearrangement. Such rearrangement processes are included in reaction I-4, which represents merely a delayed dissociation of an excited ion by either rearrangement or rupture. The time involved is considerably greater than a single vibration period (*i. e.*, $\gg 10^{-13}$ sec.) and, the longer the time required, the more probable is a rearrangement process. Examples of very slow processes corresponding to I-4 are afforded in studies of metastable ions by Hipple, Fox, and Condon (*37*). Certain states of the butane ion have been shown to have half-lives of the order of a microsecond.

$$C_4H_{10}^+ \rightarrow C_3H_7^+ + CH_3 \qquad 2 \times 10^{-6} \text{ sec.}$$
$$C_4H_{10}^+ \rightarrow C_3H_6^+ + CH_4 \qquad 1.7 \times 10^{-6} \text{ sec.}$$

In the two reactions given above, different excited states of the $C_4H_{10}^+$ ion are involved and the dissociation may involve an internal conversion process much like predissociation in photochemistry (*12*). The second dissociation is obviously a rearrangement process. The point for emphasis about step I-4 is that it itself represents a variety of possible primary modes of decomposition, including decomposition into a possible variety of stable molecules and molecule ions.

Step II is also considerably more complicated than appears on superficial examination. Of course, it is not the only neutralization step. Steps like

$$B^+ + e \rightarrow B^*$$

and

$$D^+ + e \rightarrow D^*$$

are also to be included but these complications are in the more obvious category. Less obvious, perhaps, is the reaction

$$A^{+\prime} + e \rightarrow A^{*\prime}$$

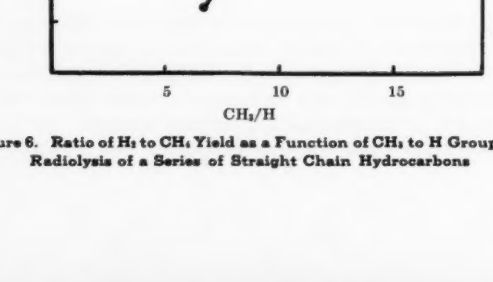


Figure 6. Ratio of H_2 to CH_4 Yield as a Function of CH_3 to H Groups in Radiolysis of a Series of Straight Chain Hydrocarbons

where another excited state of A is produced. As a matter of fact the very mechanism of step II and its variants is not too obvious. Magee and Burton (*46*) have examined its details and have concluded in regard to the isolated ion A^+ that an electron is captured in a dissociative process (*i. e.*, step III is immediately ensuant) and that the products are most probably two radicals (or atoms) one of which is excited (*i. e.*, step IIIa). In condensed systems and indeed even in gases at relatively low pressure (of the order of a few millimeters) part of the energy produced in capture may be imparted to adjoining molecules (*e. g.*, as polarization energy) and the resultant excited molecule may have time for a variety of dissociative processes, including rearrangements (step IIIb), as well as for collisional deactivation and stabilization.

A Statistical Principle. The conclusion from this rather superficial analysis of steps I, II, and III is that in radiation chemistry practically anything can happen. Differently expressed, our conclusion leads to a very important principle essentially statistical in its nature (*11*): *Where special chemical restrictions can be neglected, nature and quantity of the products are determined by nature and number of parent groups in the molecule of the substance decomposed.*

Of course, the chemistry of the substances involved can never be neglected but chemical differences are reduced to a minimum in a homologous series. An interesting study frequently cited in respect to this principle was performed many years ago by Schoepfle and Fellows (*59*). In work in which they treated a number of hydrocarbon gases with cathode rays they obtained results summarized by Figure 6. Here we find that the ratio of CH_4 to H_2 in the products is an almost linear function of the ratio of parent groups in a series of straight-chain alkanes. Honig (*38*) has called attention to a similar relationship in the α-ray induced radiolysis of a series of fatty acids. In this case, as shown in Figure 7, the ratio of H_2 to $CO + CO_2$ is an almost linear function of the number of C—H links (which is the same thing as the ratio of C—H to CO_2 groups).

Effect of State. We have already seen that the fact that most of the studies of radiation chemistry are *not* on isolated molecules affects the nature of step II and the ensuant step III. In relatively condensed systems, the "cross section" for step II is increased (*46*) and the probability of collisional deactivation before decomposition can occur is simultaneously increased. Burton (*13*) has shown that some of the data of Breger, *et al.*, on the radiolysis of liquid fatty acids are explicable on the basis of the fact that collisional deactivation and the Franck-Rabinowitch cage effect (*28*), particularly when large molecules are involved, tend to reduce decomposition via higher-energy rupture into radicals and to favor lower-energy paths of rearrangement into ultimate molecules. The particular observation explained in this way is that the yield of such compounds as $C_{15}H_{32}$ from the radiolysis of palmitic acid far exceeds that which might be expected on the purely statistical basis suggested in the previous section (*14*). However,

further work of Breger, Goodman, and Whitehead (*8*) indicates that there are other complications in the case of higher fatty acids which this picture of the effect of state does not explain.

Resonance Stabilization. A striking feature of the radiation chemistry of the hydrocarbons is the relatively high resistance of aromatic compounds and their derivatives to radiolysis. In Table 5 the contrast between aromatic and aliphatic hydrocarbons is well illustrated by data on benzene and cyclohexane taken from results of Manion (*49*), Gordon,[13] and Sworski (*64*) obtained in electron and pile irradiations of the liquids at, or near, room temperature. The pile irradiations represent the combined effects of both gammas (or X-rays) and high-energy neutrons. The symbol G is commonly used in radiation chemistry to indicate the number of molecules produced or converted per 100-e.v. input; *i. e.*, the 100-e.v. yield. Obviously, benzene is less reactive than cyclohexane by a factor of more than 100. The reasons for this resistance to radiolysis are apparently related to the fact that excited benzene, $C_6H_6^+$, and $C_6H_5^+$ are all highly resonant structures, that excited particles formed by neutralization of the ions (*i. e.*, in step II see the Eyring-Hirschfelder-Taylor theory) are also highly resonant, and that in consequence the excited particles for the most part survive long enough for occurrence either of molecular deactivation or of fluorescence before possible decomposition (*15, 16, 46*).

TABLE 5

100-e.v. Yields of Total Gas Production from Benzene and Cyclohexane (Manion, Gordon, and Sworski)

	G (total gas)	
	1.5-m.-e.-v. electrons	*Mixed pile*[a]
Benzene	0.058	0.10
Cyclohexane	7.0	..

[a] The graphite nuclear reactor of the Oak Ridge National Laboratory was employed for these experiments.

Contribution of Negative Ions. In our consideration of the fate of the electron in step I we have assumed that it enters exclusively into neutralization reactions. Such an assumption is correct for pure hydrocarbons and for many other organic substances, indeed for most substances. However, it is by no means always true. Magee and Burton (*47*) have shown that after its ejection from a molecule in step I the electron is rapidly thermalized (*i. e.*, reduced to energy corresponding to room temperature as the result of interaction with molecules which it encounters). It is thereafter captured either by a positive ion in a neutralization process (*i. e.*, step II) or by a molecule to give a negative ion. The relative probability of the two processes depends on the relative numbers of positive ions and of molecules which can give negative ions. The steady-state concentration of positive ions is determined in part by the irradiation intensity, so that figures for the relative probabilities of the two processes are given as a function of rate of positive ion production and of concentration of the species M in the reaction

$$M + e \rightarrow M^- \qquad \text{IV-1}$$

It is found that relatively few substances can react significantly for radiation chemistry according to step IV. They include only those substances which have low-lying electronic orbitals or which can capture electrons in a dissociative process yielding two particles one of which is a negative ion. Thus,

$$RX + e \rightarrow R + X^- \qquad \text{IV-2}$$

There is the added restriction that in order for either of these processes to occur to a significant extent the threshold for capture must be very low; *i. e.*, the "activation energy" for the electron capture process must be of the order of kT, the ordinary thermal energy. The two processes are illustrated by Figures 8*a* and 8*b*, respectively. The molecules involved are assumed to be formed by combination of two radicals or atoms R and X. In each case, the electron capture process is exothermal. Among examples of case 8*a* are oxygen and odd-electron molecules like NO and NO_2. Illustrative of 8*b* are alkyl halides and liquid water.

When step IV occurs the neutralization process by which the molecule A^+ disappears is

$$A^+ + M^- \text{ (or } X^-) \rightarrow \text{Characteristic reaction} \qquad \text{V}$$

For example, only a trace of oxygen must be present as an impurity in A at conveniently low irradiation levels in order to ensure that the principal neutralization reaction is step V (*17, 47*). *This result emphasizes the importance of purity of reagents in radiation chemistry if the data obtained are to have a simple interpretation.*

Ionization and Excitation Transfer. Consider a mixture of substances A and B subjected to irradiation

$$A \longrightarrow A^+ + e \qquad (1)$$
$$B \longrightarrow B^+ + e \qquad (2)$$

with ionization potentials, respectively, I_A and I_B. Now, if

$$I_A > I_B$$

the ionization may be transferred with high probability

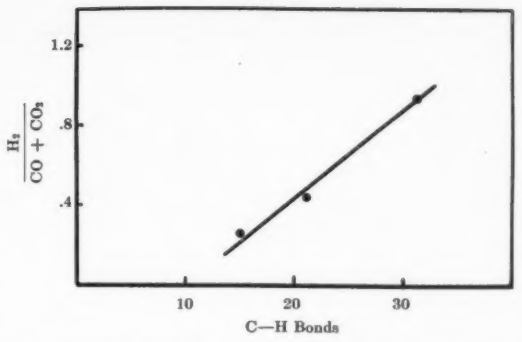


Figure 7. Ratio of Yields of H_2 to $CO + CO_2$ as a Function of Number of C—H Groups in a Series of Fatty Acids

[13] Gordon, S., and M. Burton, unpublished results.

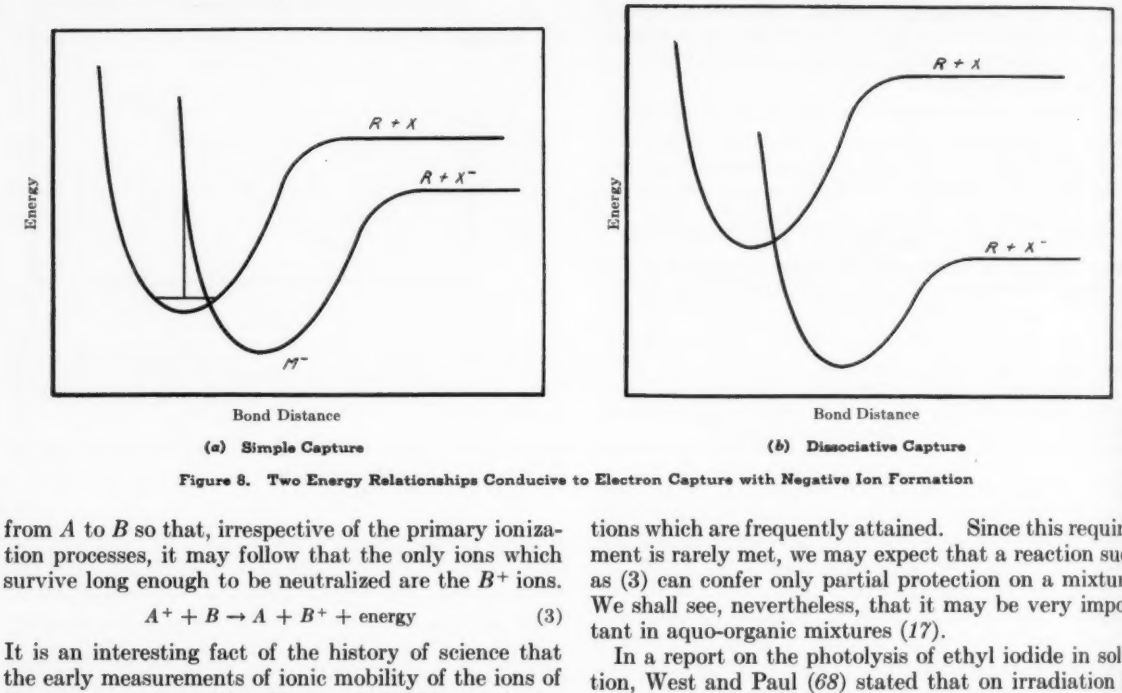


Figure 8. Two Energy Relationships Conducive to Electron Capture with Negative Ion Formation

from A to B so that, irrespective of the primary ionization processes, it may follow that the only ions which survive long enough to be neutralized are the B^+ ions.

$$A^+ + B \rightarrow A + B^+ + \text{energy} \qquad (3)$$

It is an interesting fact of the history of science that the early measurements of ionic mobility of the ions of the rare gases were vitiated by precisely this reaction so that the experimenters obtained mobilities in reality characteristic of traces of heavier impurities present. It is interesting for radiation chemistry that that particular result was misinterpreted in terms of clustering of uncharged molecules around the primarily produced ions and that this misunderstood observation in turn led to the so-called ion-cluster theory of radiation chemistry (*cf.* Lind (*44*)). The theory itself in some aspects has survived its foundation.[14]

One might expect on the basis of superficial examination of reactions (1), (2), and (3) that in a mixture of reactants A and B, in which A has the higher ionization potential, only B will be affected by the irradiation. In particular, if B itself is insensitive to irradiation, we may expect that presence of B in such a mixture may serve to protect components of the mixture from radiolysis. More careful consideration must take into account the fact that an important primary physical step in radiation chemistry is the excitation process which we have thus far neglected, namely

$$A \text{ —}\sim\rightarrow A^* \qquad (4)$$

For the process

$$A^* + B \rightarrow A + B^* \qquad (5)$$

to occur, the initial and final states must be closely coupled. The two molecular species must at the very least have nearly identical energy states for configurations which are frequently attained. Since this requirement is rarely met, we may expect that a reaction such as (3) can confer only partial protection on a mixture. We shall see, nevertheless, that it may be very important in aquo-organic mixtures (*17*).

In a report on the photolysis of ethyl iodide in solution, West and Paul (*68*) stated that on irradiation in its continuum (3130 to 2537 Å.), the quantum yield was the same in benzene as in hexane solution. Since benzene absorbs in the same region of the spectrum as does ethyl iodide, whereas hexane does not, the only reasonable conclusion is that excited benzene transfers its energy to the ethyl iodide, which in turn decomposes with characteristic yield: *i. e.*, benzene photosensitizes photolysis of ethyl iodide. The possibility that corresponding radiosensitization may be significant in radiation chemistry must not be ignored. We shall see that this factor introduces complications into straightforward studies of protection.

A closely coupled type of system, of interest in radiation chemistry, in which all primary excitation takes place in the benzene ring is afforded by the case of the photolysis of alkyl substituted benzenes. From the strictly photochemical viewpoint, there is nothing special about these compounds for there are many molecules (*e. g.*, aldehydes and ketones) in which the energy absorption is in a characteristic locus (*e. g.*, a carbonyl group) and decomposition takes place elsewhere. The special interest for radiation chemistry is the peculiar stability of these benzene derivatives. Some results on the photolysis of a series of such compounds reported by Hentz, Sworski, and this writer (*35*, *65*) are summarized in Table 6. The results have been interpreted in terms of excitation in the π-electron system of the ring and transfer of a small fraction of the excitation with maximum probability to a bond β to the ring. Other bonds are broken with less probability but most of the energy is dissipated without chemical effect.

In the radiation chemistry of these same compounds

[14] *Cf.* Garrison (*31*) who has suggested a form of cluster theory to account for polymerization of acetylene. This particular form of theory is to be differentiated from the original form criticized in detail by C. Rosenblum (*57*).

as contrasted with the photochemistry, energy is absorbed both in the rings and in the alkyl groups with primary excitation and ionization at both locales. The 100-e.v. yields were measured for the same compounds with results noted in Table 7. The data have been interpreted to indicate transfer of ionization or of excitation or of both from the side group to the benzene ring and transfer of excitation (either primary or resultant from neutralization, as in step II) from the benzene group to the side chain. Since the photochemical data indicate that at most this latter process is productive of but little decomposition, the major effect then is transfer of energy from the side group into the ring with protection of the former. The G values are characteristic of aromatic compounds and seem but slightly responsive to the fundamental reactivity of the alkyl groups. In this type of protection a group (or compound) absorbs energy from a radiation-sensitive portion of a system, decreasing chemical effects in the latter, without itself being thereby considerably affected. It has been described as "sponge-type" protection (*18*).

We may return now to further consideration of reactions (1), (2), and (3) and their consequences. Cyclohexane and benzene would appear to be particularly suitable for examination. The ionization potential of the former is 11.0 e. v. (*39*) of the latter ~9.8 e. v. (*33, 39*). It has been noted some time back (*16*) that a result of Schoepfle and Fellows (*59*) on the cathode-ray induced radiolysis of a mixture of cyclohexane and benzene appears to indicate protection of the former by the latter. This matter has recently been followed up by work of Manion and this writer (*49*). It presently appears that while there may be positive evidence of protection by the benzene, the situation may possibly be complicated by other processes. We may speculate on the following series of reactions.

$$c\text{-}C_6H_{12} \longrightarrow c\text{-}C_6H_{12}^+ + e \quad (1')$$

$$C_6H_6 \longrightarrow C_6H_6^+ + e \quad (2')$$

$$c\text{-}C_6H_{12}^+ + C_6H_6 \rightarrow c\text{-}C_6H_{12} + C_6H_6^+ + \text{energy} \quad (3')$$

TABLE 6

Quantum Yields in Photolysis of a Series of Liquid Alkyl Benzenes with Light near 2537 Å.

Compound	$\gamma(H_2) \times 10^4$	$\gamma(CH_4) \times 10^4$	$\gamma(C_2H_6) \times 10^4$
Toluene	1.0	0.04	0.05
Mesitylene	3.4	0.26	0.15
Ethylbenzene	3.2	0.11	0.09
i-Propylbenzene	2.3	0.06	0.02
t-Butylbenzene	1.2	0.03	0.02

TABLE 7

100-e.v. Yields in Radiolysis of a Series of Liquid Alkyl Benzenes by 1.5- to 1.8-m.e.v. Electrons

Compound	$G(H_2)$	$G(CH_4)$	$G(C_xH_y)$
Toluene	0.13	0.008	0.001
Mesitylene	0.24	0.018	0.002
Ethylbenzene	0.18	0.030	0.004
i-Propylbenzene	0.17	0.073	0.009
t-Butylbenzene	0.11	0.070	0.009

and also

$$C_6H_6^+ + e \rightarrow C_6H_6^* \quad (4')$$

The excited benzene formed in reaction (4′) may have energy exceeding 9 e. v. and is, therefore, much more energetic than low-energy states (<5 e. v.) possibly formed in primary excitation. Cyclohexane does not have energy states at the lower level but probably does have energy states around 9 e. v. Thus, although weakly excited benzene could not sensitize decomposition of cyclohexane, $C_6H_6^*$ as formed in reaction (4′) might do so.

$$C_6H_6^* + c\text{-}C_6H_{12} \rightarrow C_6H_6 + c\text{-}C_6H_{12}^* \quad (5')$$

The $c\text{-}C_6H_{12}^*$ thus formed would be unstable and consequently reduce the protective influence of reaction (3′). It will be interesting to discover what this study will finally show.

Water. The radiation chemistry of water and of aqueous systems is so important for theory, for technology, and for radiobiology and radiology that a separate review might well be devoted to it. Various aspects have been described and studied by Allen (*1*),[15] by Ghormley and Allen (*32*), by Weiss and his collaborators (*63*), by Dainton (*22*), and by this writer (*11*). The reactions in pure water may be summarized in the following scheme.

$$H_2O \longrightarrow H_2O^+ + e \quad (1)$$

$$H_2O^+ + \text{aq.} \rightarrow H_2O^+ + OH \quad (2)$$

The distance between successive steps (1) and (2) in the ionization column depends on the velocity of the incident particle. In heavy-particle irradiation, successive ionizations and accompanying hydroxyl radicals may be produced close together. There is in such case a good possibility that the radicals may react with each other early in their history.

$$2OH \rightarrow H_2O_2 \quad (3)$$

On the other hand if the hydroxyl radicals are formed many molecules apart, as they may be in fast particle irradiation (*e. g.*, highly energetic electrons), a much more probable path of disappearance would involve hydrogen. Let us consider the fate of the electron produced in reaction (1). It is rapidly thermalized and, as we have already seen, will be captured by liquid water in a dissociative process.

$$e + H_2O\text{-aq.} \rightarrow OH^-\text{-aq.} + H \quad (4)$$

Hydrogen atoms formed in the latter process can combine with each other

$$H + H \rightarrow H_2 \quad (5)$$

or react with hydroxyl radicals, particularly if the latter have been produced by fast particle bombardment.

$$H + OH \rightarrow H_2O \quad (6)$$

[15] Allen has also prepared a review of the radiation chemistry of aqueous systems for the volume on "Chemical Effects of High-Energy Radiation" (M. Burton, Editor) of the National Nuclear Energy Series, McGraw-Hill Book Company, New York, which still awaits publication.

Reaction (6) is not the only path by which hydroxyl can disappear. Allen (*1*) has pointed out an interesting sequence similar to the reaction chain in the explosive photochemical reaction between hydrogen and chlorine. After the first step $Cl_2 + h\nu \rightarrow 2Cl$, we have the sequence

$$Cl + H_2 \rightarrow HCl + H$$
$$H + Cl_2 \rightarrow HCl + Cl$$

In pure hydrogen and chlorine chains of 10^5 to 10^6 steps have been reported. Allen suggests that the analogous chain

$$OH + H_2 \rightarrow H_2O + H \quad (7)$$
$$H + H_2O_2 \rightarrow H_2O + OH \quad (8)$$

may be responsible for low G values in liquid water and for difficulty in observation of products in electron bombardment at all. He postulates that any means which would interrupt the sequence (7), (8) would increase the yield of H_2, of H_2O_2, and O_2 formed from decomposition of H_2O_2. It is known, for example, that although products can be observed in electron irradiation of pure water only with the greatest difficulty, small concentrations of Br^- or I^- ion are sufficient to guarantee production of easily collectable H_2, at a rate determined by concentration of the halogen ion. On the other hand Cl^- is unable to produce this effect, as are a number of other ions of high electron affinity. He indicates that the important reaction is

$$X^- + OH \rightarrow X + OH^- \quad (9)$$

Depending on the redox potential of the reaction and the concentration of X^-, the steady-state concentration of OH is reduced in such a way as to prevent the back-reaction sequence (7), (8) and to increase the yield of hydrogen and accompanying products.

Any substance which reduces the concentration of H or OH behaves similarly to Br^- and I^- ions. Dissolved oxygen has such an effect involving H atoms:

$$H + O_2 \rightarrow HO_2 \quad (10)$$

The latter radical (hydroperoxyl) is more active both as a reducing agent and as an oxidizing agent than H_2O_2 but it is less active than either free H or free OH. The HO_2 can yield hydrogen peroxide by capture of an additional H atom and the latter might then decompose to keep the process going. Although air-free pure water is barely affected by energetic electrons, the G-value of electrolytic gas ($H_2 + {}^1/_2O_2$) production in water containing a small amount of oxygen is readily determined.

In aqueous solutions of oxidizable or reducible substances, the primary effect of radiation is for the most part on the water, in which free H and OH are produced. It is action of the latter entities which is responsible for the effects observed. Thus, it is not surprising that in studies of oxidation, for example, of a number of inorganic ions, in the early stages of the reaction, G values are obtained which are constant and independent of the ion oxidized.

On the other hand, the primary effect of radiation on the dissolved or suspended constituent, particularly when it is organic, must not be neglected. This effect becomes more important when the aqueous phase or the organic phase is dispersed in droplet form in the other (*17*). Imagine an organic substance A which does not yield negative ions by electron capture. According to calculations of this writer[16] the ionization potential of water in the liquid state is probably much less than 7 4 e. v. The ionization potential of any organic substance A is probably considerably higher. We note then that if ionization occurs in A

$$A \rightsquigarrow A^+ + e \quad (11)$$

the electron involved will be captured in the water immediately adjacent to the main body of the organic material.

$$H_2O\cdot aq. + e \rightarrow H + OH^-\cdot aq. \quad (12)$$

The ensuing reaction depends on the immediate fate of A^+. If it can exchange ionization with the water, we have

$$A^+ + H_2O\cdot aq. \rightarrow A + H_3O^+ + OH \quad (13)$$

again immediately adjacent to the main body of A. Depending on the character of A, it will either be oxidized by OH or reduced by H or both reactions might occur. On the other hand, if the step (13) cannot occur, the only fate available to A^+ would probably involve the reaction

$$A^+ + OH^- \rightarrow \text{products}$$

We may note finally in the radiation chemistry of water the anisotropic distribution of H_3O^+ and OH^- ions, particularly in cases of heavy particle bombardment. In the ionization column itself, local concentrations of H_3O^+ may correspond to pH of zero or less while in the sheath around such a column the pH may rise to 12 or 13. Of course, rapid diffusion, mixing, and interaction of H_3O^+ and OH^- prevent maintenance of such an artificial situation but the fact must not be neglected that these momentary extreme and highly local pH values may produce characteristic effects in colloidal, potentially colloidal, and biological systems.

Radiobiology. At this point some mention of the radiation chemical aspects of radiobiology is desirable. A very satisfactory introduction to this field has been written by Lea (*43*), who gave particular attention to the elementary physical phenomena involved. We shall consider merely those aspects in which the elementary phenomena discussed in the previous section are pertinent.

Consider a system of simple biological units (*e. g.*, particles of virus, bacteriophage, chromosomes) suspended in an aqueous medium subjected to irradiation. As a result of the irradiation these biological entities suffer a change in some property which is readily meas-

[16] For a number of papers by several authors on the general subject of radiobiology *cf.* National Research Council Symposium on Radiobiology, O. Oberlin, June 15, 1950, in press.

urable or detectable. Not all of the entity is necessarily affected but some prosthetic group responsible for a positive reaction to the test applied is affected. It is even possible that a portion of the entity not in the prosthetic group has been damaged without injury to that group; if so, our test does not reveal that fact. A test frequently applied is the ability of the entity or organism to reproduce itself. In such circumstance the lethal effect of the irradiation is studied and it is customary to plot a survival curve as a function of dosage. In Figure 9 we show, for example, in curves *a*-1 and *b*-1 two forms of the same survival curve, one the usual plot, the other logarithmic. The simplest interpretation of this type of curve is that a single "hit" within a particular target area is adequate for a kill. More than one such hit is without further effect. The "hit" is identified with an ionization act and the target has frequently been identified with the biological entity.

By mathematical analysis of survival curves such as shown in Figure 9 obtained on various irradiations (soft and hard X-rays, alphas, etc.) it has proved possible to obtain an estimate of the size of the target. Slightly different target sizes are obtained depending on the nature of the radiation, and the computed target sizes appear uniformly smaller than are obtained by electron microscopic measurement of the dehydrated biological material. Furthermore, for a variety of reasons (*e. g.*, partial clumping of the particles) some departure from true exponential type survival curves given in Figure 9, the analytical expression for which is $N = N_0 e^{-x}$, may be expected. A more significant departure is obtained when more than one hit is required to affect a particle. The analytical expression for survival then is $N = N_0 - N_0(1 - e^{-x})^n$, where n is the number of necessary hits. Sigmoid curves, shown by lines 2,3,4 in Figure 9, are then obtained. There are also cases in radiobiology where more than one target exists, a hit in any one of which produces a detectable mutation.

In our present discussion we confine ourselves to the simple case of a single hit effective in a particular target volume. We note also that the principal primary effect cannot be exclusively in the biological entity for it has been noted that removal of oxygen from the system or introduction of substances like cysteine necessitates a much larger dose of radiation in a system for production of a particular effect; *i. e.*, the mean lethal dose is increased. We propose to examine, in very introductory fashion, the so-called "target theory" of radiobiology (a theory incidentally which is essentially mathematical) in terms of ideas so far developed for the radiation chemistry of aqueous systems.

In consideration of radiobiological phenomena, the following factors are pertinent.

Most biological materials are sensitive to powerful oxidizing and reducing agents and to extreme conditions of pH. In the ion track of a high-energy radiation passing through water there is a local high concentration of free OH radicals and H^+ ions. In the cylinder immediately surrounding the track, there is a concentration not quite so high of free H atoms and OH^- ions. If any of these entities can reach a prosthetic group of the biological entity, destructive action may ensue.

Destructive action of free H and OH and of extreme pH values is limited by the diffusion ranges of the entities involved. Their diffusion ranges are in turn limited by their extreme chemical activities. Thus, coulombic forces may attract oppositely charged ions very rapidly toward each other and reduce their effectiveness, while the action of OH on free H or on dissolved H_2 limits the possibility that a particular entity may have a destructive biological effect.

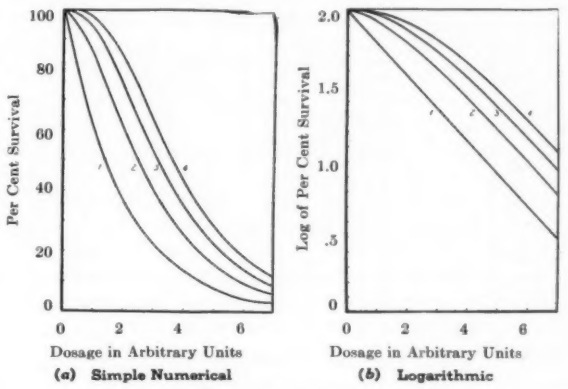


Figure 9. Survival Curves

1, Exponential: a single hit is lethal. *2*, Sigmoid: two hits necessary for a kill. *3*, Sigmoid: three hits necessary for a kill. *4*, Sigmoid: four hits necessary for a kill.

A "hit" (*i. e.*, an ionization) in the water has destructive effect only if the active entities are within range of the biological entity. In the ion track of a heavy (slow-moving) energetic particle such as an alpha ray, free OH radicals are produced sufficiently close together so that local high concentrations of H_2O_2 may be produced. These are less active chemical entities than the free radicals and may consequently diffuse further without disappearance in a succeeding process. Since their diffusion range is greater they may have destructive effect on a biological entity at a greater distance from the ion tracks. The "target" size is thus increased for alpha or deuteron radiation and this effect has indeed been found (*53*).

Another way by which the life of active radicals may be increased is to make them less active. We have seen that free oxygen has precisely that effect.

$$H + O_2 \rightarrow HO_2$$

The hydroperoxyl radical, being less active than either H or OH, survives longer and consequently diffuses farther. Thus, by its presence oxygen increases the range of destruction of the ionization column of fast moving particles (*e. g.*, betas and high-energy electrons expelled

in X-ray absorption). Consequently, the lethality of a particular dose of X- or gamma radiation is increased by oxygen. Oxygen does not have a corresponding effect for alpha radiation. The explanation in that case is probably that advanced in another connection by Dainton (*22*) and by Magee (*48*). In order for a solute to react significantly with free radical intermediates it must be present in concentration of the same order as the local concentration of the radicals in the ionization column. Such a concentration of oxygen is not readily attainable when the local high radical concentrations characteristic of slow-particle processes are involved.

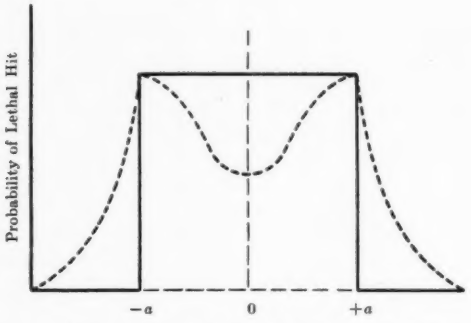


Figure 10. Lethality of a Hit

The effect of cysteine in reduction of the lethality of radiation in the presence of oxygen may be explained in terms of its oxidation by HO_2 before the latter can diffuse to (or perhaps react with the less sensitive) biological material. Any active reducing agent, not itself capable of reaction with oxygen but sensitive to the more active hydroperoxyl radical, would act similarly. Thus, HCN has been found to be effective in protection of bacteria and lower organisms and Dale has reported, interestingly enough, that the nontoxic thiourea protects simple amino acids from radiation-induced oxidation in aqueous solution containing oxygen. Weiss and his co-workers found that under X-irradiation benzene is oxidized to phenol in aqueous solution either in the presence or absence of oxygen (*63*). Schuler[17] reports that the presence of thiourea causes 90 to 95 per cent inhibition of this reaction.

A hit in the biological entity itself is not necessarily effective in terms of the tests made (*e. g.*, lethality under certain conditions). The hit must be in such locale that ultimately a prosthetic group is adversely affected. The hit need not be in the prosthetic group itself but the prosthetic group must ultimately receive the energy in one of the ways described in the section on ionization and excitation transfer. Various other factors can decrease the probability of a lethal hit within the biological entity. The hit may be in a resonant region so that ionization and neutralization occur without destructive action. The hit may be deep within the entity and actually cause incipient dissociation which is prevented by a Franck-Rabinowitch cage effect. The hit may be potentially destructive but the energy can be tapped off to give protection, either of a "sponge" type already described in which the energy is simply ineffectively degraded and dissipated or of the "sacrificial" type in such a way that a nonprosthetic portion of the biological entity absorbs the injury. It may also be true that the bigger the entity the smaller the mass fraction of the prosthetic group.

However, it is not necessarily true that a hit within the biological entity produces its entire effect within that entity. In the section on water the special possibilities in a droplet dispersion of organic material in water are described. The electron emitted in the ionization act within the biological entity (*cf.* reaction (12) of that section) may be captured in the adjacent water to yield free H and OH^- immediately adjacent to the entity and it is even possible that the ionization itself may transfer to the water to give free OH radical and H^+ ion also in close proximity to the entity. Thus, the primary effect of radiation on the biological entity may be transferred into the immediately adjacent aqueous layer to produce highly destructive chemical entities which in turn can produce detectable effects if they act upon a prosthetic group.

The radiation-chemical nature of the target in target theory is perhaps to be seen in terms of the model summarized in Figure 10. For the reason already given, even if all parts of the target were equally sensitive (see solid line), a hit within the target would have somewhat less than unit probability of being lethal. The dipped dotted line within the entity reflects the possibility that the Franck-Rabinowitch cage effect becomes more probable with large entities. Perhaps it may be such an effect which accounts for the fact that the calculated target dimensions (determined from survival curves and similar data) deviate more from the geometric size of the biological entity with increased size of the latter. The dotted line outside the entity reflects the fact that a hit in the water itself may be destructive but this probability drops sharply as the distance increases.

We may conclude with the statement, perhaps obvious from the fact that ultraviolet light itself has injurious effects on certain organisms, that the lethal potentialities of primary excitation, particularly in the biological particle itself, must not be neglected in a complete exposition.

Solids. The radiation chemistry of solids is also a subject which merits its own review. Anything resembling a complete summary cannot be attempted here. The endeavor instead is to relate briefly certain aspects of the effects on solids which are producible only by high-energy radiation.

The most outstanding effect of this kind is the knocking-out process caused by high-energy neutrons. This phenomenon was predicted by E. P. Wigner (*9*) and shortly thereafter discovered by the Radiation Chemistry Section of the Metallurgical Laboratory. It was

[17] SCHULER, R. E., private communication.

found (*9*) that atom displacements produced in pure graphite by such effects were reflected in readily detectable changes in electrical resistance, elastic modulus, and thermal conductivity. Since the assumption is that the displaced atoms do not return to characteristic lattice points this "Wigner effect" in solids has been called *discomposition* (*9*). Seitz (*60*) has examined this subject on a theoretical basis and has calculated effects producible in beryllium, graphite, diamond, aluminum, silicon, and germanium by 5-m. e. v. alphas, 20-m. e. v. protons, and 2-m. e. v. neutrons. Noting that the depth of penetration of the protons, for example, is about 0.1 cm. in these materials, Seitz has calculated that about 10 per cent of the atoms in such a layer would be displaced by 1 coulomb cm.$^{-2}$ of such protons, a level readily attainable in cyclotron bombardment.

The effects of high-energy radiation on ionic crystals are different principally in degree rather than kind from those producible by ultraviolet light except in one or two aspects.

Since in order for ultraviolet light to be effective it must be absorbed, the light is usually absorbed in a very thin layer and studies are usually limited in that regard. The very penetrating nature of high-energy radiation has extended the nature of the studies which can be conveniently conducted and has revealed the existence of new types of color centers not found in photochemical work (*61*), as well as vacancy migration during production of color centers (*26*).

Furthermore, certain ionic crystals, of which lithium fluoride is the outstanding example, do not absorb light in the attainable ultraviolet region. Lithium fluoride, however, can be affected by high-energy radiation and the effects obtained have proved of great interest. Some of the results obtained are described in papers by Pringsheim and his co-workers (*19*), Penneman (*51*), and Powers (*55*). New types of color centers not reported in any other case have been described.

Daniels has suggested that the thermoluminescence of minerals subjected to low-intensity-level but high-energy radiation over long periods of time may be used both to identify the minerals from similar sources and to reveal the existence of useful concentrations of radioactive deposits (*23*, *5*). Ghormley has been studying the appearance of this luminescence in ionic crystals as a function of temperature in an effort to identify low-lying electron traps.[18]

RESEARCH POSSIBILITIES

There is a temptation at the conclusion of a paper like this to suggest interesting fields for investigation. The writer has been asked specifically about possibilities of various fields of study and has in each case replied that the field is so open that all that is needed is to begin work of any kind. An effort to understand the first results obtained will lead one in deeper and deeper and, if he persists for any time at all, he will shortly become an expert.

[18] GHORMLEY, J. C., private communication, to be published.

Various subjects which require more attention are listed below. Some are already under investigation but additional work in those cases is needed. No references are given in this section but references earlier in this paper may bear on some of these subjects.

There is need for adequate radiation chemical monitors of use particularly for establishment of the effectiveness of dosage of mixed radiation under conditions similar to those found in biological material. Such monitors are required over a wide range of dosage from a fraction of a roentgen[19] (or an equivalent roentgen) for biological purposes to millions of roentgens for straightforward radiation chemical purposes.

The reasons for low yields in certain radiation chemical processes invite particular attention because they may give much-needed clues as to mechanism and methods of protection. It is desirable, in part, to discover whether such low yields are the result of back reaction, of low yield of a primary process, or of external protective mechanisms. Possibilities in the study of aromatic derivatives have been barely tapped. The behavior of mixtures not only bears on the nature of protection but also may have important industrial significance in deliberately contrived reactions. From the more theoretical point of view radiation chemical reactions should be studied to determine how internal conversion and energy transfer affect yields. In this connection, the explanation of the ion spectra of various substances in mass spectrometry has already proved a difficult problem and a fruitful one for study.

The sources of compounds necessary for life are a continual mystery. Before there was photosynthesis there must have been chlorophyll. Where did it come from? What was the nature of this protophotosynthesis? Were high-energy radiations from outer space involved and, if so, how?

Finally, many of the problems of radiation chemistry of the laboratory are related both to the common, easily attainable, glow-discharge processes and to the more mysterious nuclear reactor. Both are of potential importance in special applications to the chemical industry and such possibilities should certainly tempt the more "practical" among us.

ACKNOWLEDGMENTS

The author wishes to express his appreciation to Dr. R. R. Hentz and to Dr. Dean Anderson who have assisted greatly in the preparation of this paper.

LITERATURE CITED

(1) ALLEN, A. O., "The Science and Engineering of Nuclear Power," Addison-Welsey Press, Cambridge, Massachusetts, 1949, II, Chap. 13, p. 207; also, *J. Phys. Colloid Chem.*, 52, 479 (1948).

(2) BECQUEREL, H., *Compt. rend.*, 122, 420, 501, 559, 689, 762, 1086 (1896).

[19] A roentgen of X- or gamma radiation is defined as the quantity "such that the associated corpuscular emission per 0.001293 g. of air (*i. e.*, 1 cc. of dry air at 0° and 760 mm.) produces, in air, ions carrying 1 e. s. u. of quantity of electricity of either sign.'

(3) BORN, M., "Atomic Physics," 4th ed., Blackie and Son, London, **1946**, p. 64.
(4) BOTHE, W., *Z. Electrochem.*, **28**, 459 (1922).
(5) BOYD, C. A., *J. Chem. Phys.*, **17**, 1221 (1949).
(6) BRAGG, W. H., *Phil. Mag.* [6], **13**, 333 (1907).
(7) BREGER, I. A., *J. Phys. Colloid Chem.*, **52**, 551 (1948).
(8) BREGER, I. A., C. GOODMAN, AND W. L. WHITEHEAD, presented before the Division of Physical and Inorganic Chemistry at the 116th Meeting of the American Chemical Society, Atlantic City, September 20, 1949.
(9) BURTON, M., *J. Phys. Colloid Chem.*, **51**, 611 (1947).
(10) BURTON, M., *Chem. Eng. News*, **26**, 1764 (1948).
(11) BURTON, M., *Ann. Rev. Phys. Chem.*, **1**, 113 (1950).
(12) BURTON, M., AND G. K. ROLLEFSON, *J. Chem. Phys.*, **6**, 416 (1938).
(13) BURTON, M., *J. Phys. Colloid Chem.*, **52**, 810 (1948).
(14) BURTON, V. L., *J. Am. Chem. Soc.*, **71**, 4117 (1949).
(15) BURTON, M., *J. Phys. Colloid Chem.*, **51**, 786 (1947).
(16) BURTON, M., *Proc. Conf. on Nuclear Chem.*, Chem. Inst. Canada, 179 (1947).
(17) BURTON, M., Army Chemical Corps, Symposium IV, in press (1950); also printed in Farkas Memorial Volume.
(18) BURTON, M., S. GORDON, AND R. R. HENTZ, Paper presented at Celebration of 50th Anniversary of Discovery of Radium, Paris, July 17, 1950; publication forthcoming.
(19) CASLER, R., P. PRINGSHEIM, AND P. YUSTER, *J .Chem. Phys.*, **18**, 887 (1950).
(20) CURIE, M., P. CURIE, AND G. BEMONT, *Compt. rend.*, **127**, 1215 (1898).
(21) CURIE, M., "Traité de Radioactivité," Gauthier-Villars, Paris, **1910**, Vol. 1, p. 247.
(22) DAINTON, F. S., *J. Phys. Colloid Chem.*, **52**, 490 (1948).
(23) DANIELS, F., Army Chemical Corps, Symposium IV, in press (1950).
(24) DUANE, W., *Compt. rend.*, **146**, 958 (1908).
(25) EDWARDS, R. R., AND T. H. DAVIES, *Nucleonics*, **2**, 44 (1948).
(26) ESTERMANN, I., W. J. LEIVO, AND O. STERN, *Phys. Rev.*, **75**, 627 (1949).
(27) EYRING, H., J. O. HIRSCHFELDER, AND H. S. TAYLOR, *J. Chem. Phys.*, **4**, 479, 570 (1936).
(28) FRANCK, J., AND E. RABINOWITCH, *Trans. Faraday Soc.*, **30**, 120 (1934).
(29) FRICKE, H. E., J. HART, AND H. P. SMITH, *J. Chem. Phys.*, **6**, 229 (1938).
(30) FRIEDLANDER, G., AND J. W. KENNEDY, "Introduction to Radiochemistry," John Wiley & Sons, New York, **1946**, p. 100.
(31) GARRISON, W. M., *J. Chem. Phys.*, **25**, 78 (1947).
(32) GHORMLEY, J. C., AND A. O. ALLEN, *Oak Ridge Natl. Lab. Rept.* ORNL 128, 25 pp., Atomic Energy Commission, October, **1948**.
(33) GLOCKLER, G., AND S. C. LIND, "The Electrochemistry of Gases and Other Dielectrics," John Wiley & Sons, Inc., New York, **1939**.
(34) HAHN, P. F., J. P. B. GOODELL, C. W. SHEPPARD, R. O. CANNON, AND H. C. FRANCIS, *J. Lab. Clin. Med.*, **32** 1442 (1947).
(35) HENTZ, R. R., AND M. BURTON, *J. Am. Chem. Soc.*, **73**, 532 (1951).
(36) HEVESEY, G., AND F. A. PANETH, "A Manual of Radioactivity," 2nd ed., Oxford University Press, **1938**, p. 247.
(37) HIPPLE, J. A., R. E. FOX, AND E. U. CONDON, *Phys. Rev.* **69**, 347 (1946); J. A. HIPPLE, *Phys. Rev.*, **71**, 594 (1947); *J. Phys. Colloid Chem.*, **52**, 456 (1948).
(38) HONIG, R. E., *Science*, **104**, 27 (1946).
(39) HUSTRULID, A., P. KUSCH, AND J. T. TATE, *Phys. Rev.*, **54**, 1037 (1938).
(40) JOLY, J., *Phil. Mag.* [6], **13**, 381 (1907).
(41) KOHMAN, T. P., *Am. J. Phys.*, **15**, 356 (1947).
(42) LANGER, A., *J. Phys. Colloid Chem.*, **54**, 618 (1950).
(43) LEA, D. E., "Actions of Radiation on Living Cells," Cambridge University Press, **1947**.
(44) LIND, S. C., "Chemical Effects of Alpha Particles and Electrons," Reinhold Publishing Company, New York, **1935**.
(45) LIND, S. C., *Sitzb. Akad. Wiss. Wien IIa*, **120**, 1709 (1911).
(46) MAGEE, J. L., AND M. BURTON, *J. Am. Chem. Soc.*, **72**, 1965 (1950).
(47) MAGEE, J. L., AND M. BURTON, *ibid.*, **73**, 523 (1951).
(48) MAGEE, J. L., Symposium IV, Army Chemical Corps, Army Chemical Center, Maryland, September, 1950.
(49) MANION, J. P., AND M. BURTON, *J. Phys. Colloid Chem.*, **55**, in press (1951).
(50) MUND, W., "L'Action Chimique des Rayons Alpha en Phase Gazeuse," Hermann et Cie., Paris, **1935**.
(51) PENNEMAN, R. A., Atomic Energy Commission Declassified Document No. 1859, 1948.
(52) PETRAUSKAS, A. A., L. C. VAN ATTA, AND F. E. MYERS, *Phys. Rev.*, **63**, 389 (1943).
(53) POLLARD, E. C., AND F. FORRO, JR., *Science*, **109**, 374 (1949).
(54) PORTER, R., D. C. BARDWELL, AND S. C. LIND, *J. Am. Chem. Soc.*, **48**, 2603 (1926).
(55) POWERS, J. A., M.S. Thesis, University of Notre Dame, 1950.
(56) ROENTGEN, W. C., *Sitzungsberg. Wurzburger Physik-Medic. Gesellschaft* Jahrg. **1895**; reprinted *Ann. Physik*, **64**, 1 (1898); translation by A. STANTON, *Science*, **3**, 277, 726 (1896). *Cf.* O. GLASSER AND M. BOVERI, "Wilhelm Conrad Roentgen and the Early History of the Roentgen Rays," John Bale, Sons, and Daniellson, Ltd., London, **1934**.
(57) ROSENBLUM, C., *J. Phys. Chem.*, **52**, 474 (1948).
(58) RUTHERFORD, E., J. CHADWICK, AND C. D. ELLIS, "Radiations from Radioactive Substances," Cambridge University Press, **1930**, pp. 179 *et seq.*
(59) SCHOEPFLE, C. S., AND C. H. FELLOWS, *Ind. Eng. Chem.*, **23**, 1396 (1931).
(60) SEITZ, F., *Discussions of Faraday Soc.*, **5**, 271 (1949).
(61) SEITZ, F., *Revs. Modern Phys.*, **17**, 384 (1946).
(62) SILVERMAN, A., J. CHEM. EDUC., **22**, 482 (1945).
(63) STEIN, G., AND J. WEISS, *J. Chem. Soc.*, 3245, 3254 (1949).
(64) SWORSKI, T. J., AND M. BURTON, *J. Am. Chem. Soc.*, **73**, in press (1951).
(65) SWORSKI, T. J., R. R. HENTZ, AND M. BURTON, *J. Am. Chem. Soc.*, **73**, in press (1951).
(66) SZILARD, L., AND J. A. CHALMERS, *Nature*, **134**, 462 (1934).
(67) USHER, F. L., *J. Chem. Soc.*, **97**, 389 (1910).
(68) WEST, W., AND B. PAUL, *Trans. Faraday Soc.*, **28**, 688 (1932).
(69) WILLIAMS, JR., R. R., AND W. H. HAMILL, *J. Am. Chem. Soc.*, **72**, 1857 (1950).

THE CONGRESS AT KARLSRUHE

CLARA deMILT
Newcomb College, Tulane University, New Orleans, Louisiana

THE Congress at Karlsruhe, which met September 3, 4, and 5 in 1860, was the first international congress in science and as such set the pattern for the congresses that have been held since this time.[1] August Kekulé has been rightly considered as the originator of the idea and Anschütz[2] believes that in the calling of this meeting Kekulé rendered an especially great service to the advancement of chemistry. A case might certainly be made for the opinion that this was Kekulé's greatest contribution to the development of chemistry. Without the help of Adolphe Wurtz and Carl Weltzien, however, the Congress would have been just another of Kekulé's dreams. In a letter to Weltzien, written from Ghent, March 14, 1860, Kekulé says of Wurtz, "Wurtz is, according to my opinion, the most important personality (in the organization of this meeting) and if he will join with us on this point the thing is half accomplished."[3] In the fall of 1859 Weltzien had agreed to have the meeting at the Technische Hochschule in Karlsruhe and to function as business manager, and during the winter of 1859 he sounded out the leading chemists of Europe on the proposed meeting. At the end of March, 1860, Kekulé and Weltzien met with Wurtz in Paris, and definite plans were then made for the conference. A circular was sent to the most outstanding chemists of Europe asking for their cooperation. As this first appeal was favorably received the time of the meeting was set and the announcements were sent out by Weltzien. They were written in English, French, and German. It is interesting to note that although the German version was dated July 10 the English one was dated July 1.[4] A translation of the German one follows.

Karlsruhe, July 10, 1860

Gentlemen:

Chemistry has reached a state of development when to the undersigned, it seems necessary that a meeting of a great number of chemists, active in this science, who are called upon to do research and teach, be held so that a unification of a few important points shall be approached.

The undersigned, therefore, invite to an international congress all those colleagues who on the basis of their attitude and work have a right to voice an opinion in this science.

Such a congress in the opinion of the undersigned, however, would not be in the position to make definite binding conclusions, but through a thorough discussion many misunderstandings might be removed; especially an agreement in regard to the following main points might be made easier:

More precise definitions of the concepts of atom, molecule, equivalent, atomicity, alkalinity, etc.; discussion on the true equivalents of bodies and their formulas; initiation of a plan for a rational nomenclature.

Although it is not expected that the meeting that is being called will succeed completely in harmonizing the divergent opinions, nevertheless, the undersigned are of the conviction that it should be possible by this means at least to prepare the way for a desirable agreement on these important questions.

Furthermore, a commission might be appointed whose task it would be to pursue further these questions. This commission might suggest that academies and other learned societies, which have the necessary facilities, take part in the solution of the questions stated above.

The meeting is to convene on September 3, 1860, at Karlsruhe. Our colleague, Weltzien, has taken over the function of business manager until the definite constitution of the congress has been drawn up and will open the latter on the designated day in the morning at nine o'clock.

It is urgently requested that those gentlemen who intend to attend the congress notify our colleague as soon as possible, so that the choice of the place of the meeting may be arranged according to the size of the congress.

Furthermore, the undersigned request that those receiving circulars take part in their distribution among scientific circles, so that those whose names have been inadvertently omitted may receive the announcement.

By Babo, Balard, Beketoff, Boussingault, Brodie, R. Bunsen, Bussy, Cahours, Cannizzaro, H. Deville, Dumas, Englehardt, O. L. Erdmann, v. Fehling, Frankland, Frémy, Fritzsche, Hlasiwetz, A. W. Hofmann, Kekulé, H. Kopp, J. v. Liebig, Malaguti, Marignac, E. Mitscherlich, Odling, Pasteur, Payen, Pebal, Peligot, Pelouze, Piria, Regnault, Roscoe, A. Schötter, Socoloff, Staedeler, Stas, Ad. Strecker, C. Weltzien, H. Will, W. Williamson, F. Wöhler, Ad. Wurtz, Zinin.

Of the above forty-five who signed the summons, twenty came: Babo, Boussingault, R. Bunsen, Cannizzaro, Dumas, O. L. Erdmann, v. Fehling, Hlasiwetz, Kekulé, H. Kopp, Marignac, Odling, Pebal, Roscoe, Stas, Ad. Strecker, Weltzien, H. Will, Wurtz, Zinin.

So far as I know none of the announcements reached the United States.[5] If some of them did, the date of arrival would hardly have given the chemists of this country time enough to make plans to attend the meeting. It is my opinion that Wolcott Gibbs and T. Sterry Hunt would have made the effort to attend the Congress had they received the announcement, as both of them had followed with interest the development of the unitary system and the new type theory.[6]

The official report of the Congress was written by Wurtz, one of the five secretaries elected on the first day of the meeting, and was deposited in the Archives

[1] BOGERT, M., *Chem. Eng. News*, **27**, 1992 (July 11, 1949).
[2] ANSCHÜTZ, RICHARD, "August Kekulé," **1929**, Vol. I, p. 201.
[3] ANSCHÜTZ, R., *ibid.*, p. 183.
[4] ANSCHÜTZ, R., *ibid.*, p. 671.

[5] Louis Posselt, registered from Mexico, had worked in Mexico from 1849 when he left Heidelberg, but he had returned to Germany early in 1860.

[6] HUNT, T. S., *Am. J. Sci.* [2], **4**, 93–100; 171–85 (1847); [2], **6**, 170–8, (1848); [2], **31**, 256–263, (1861). GIBBS, W., *ibid.* [2], **31**, 246–51 (1861).

of the Technical College at Karlsruhe. It has been published in the account of the development of chemistry in Karlsruhe by Karl Engler, who wrote this portion of "The Presentation Volume for the Celebration of the Fortieth Anniversary of the Rule of his Royal Highness the Grand Duke Friedrich of Baden," Karlsruhe, 1892.[7] Richard Anschütz published the report of Wurtz in the original French as an appendix to Volume One of his life and work of Kekulé.[8] *Le Moniteur Scientifique* for October 15, 1860 (t. II, 984–6), contains a short account of the meeting which differs in minor details from the official report. From the context one would assume that the information must have been obtained not directly from Wurtz but from l'abbé Moigno and Louis Grandeau. *Chemical News* for October 6, 1860, (Vol. 2, 203) contains a very brief report. Another report was published in the same volume, pages 226, 227. This was placed under the heading, "Chemical Notices from Foreign Sources" and must have been sent to the editor by the journal's foreign correspondent in Paris, l'abbé Moigno[9] as in the details given it is like the report in *Le Moniteur Scientifique*. According to both accounts, after the sitting of the first meeting, September 3, closed, "the members fraternized together at a banquet laid for 120 persons in the large hall of the Museum. This supplementary meeting, which was not mentioned in the programme, was by no means the least scientific, the least relished, nor, above all, the least substantial, as we learn from the Abbé Moigno."

There must have been reports like these in a German weekly, but no reference has been made to a report in published comments on the Congress. In the St. Petersburg *Gazette* No. 280, 1860, appeared a letter from Mendeleev to his former teacher, A. A. Voskresenskiĭ, Professor of Chemistry in the University of St. Petersburg.[10] Mendeleev was twenty-six in 1860. In 1859 he had gone to Paris to study under Victor Regnault, probably the ablest and most experienced physical chemist at the Sorbonne. From Paris he had gone to Heidelberg and from this University he journeyed to Karlsruhe. His appreciation of the issues involved in the discussions at the meeting, of the importance of the debates, and of the value of this Congress in the future development of chemistry is amazing, and show the outstanding genius of this scientist.

The chemical Congress just ended in Karlsruhe produced such a remarkable effect on the history of our science that I consider it a duty, even in a few words, to describe all the sittings of the Congress and the results which it reached.

The essential reason for calling an international chemical congress was the wish to clarify and, if possible, agree on the basic differences which exist between the followers of different chemical schools. At first, Kekulé proposed to settle many questions: the question of the difference of molecules, atoms, and equivalents; the question of the size of the atomic weights, *i. e.*, whether the "particle" of Gerhardt or the particle of Berzelius as changed by Liebig and Poggendorf, and now used by most men, should be accepted; further, the question of formulas, and finally, even about the case where, in the present state of science, we should consider the reasons for chemical effects. But at the first sitting, September 3, the meeting found it impossible in such a short time to clarify such a great number of questions, and so resolved to settle only on the first two.

There was chosen a commission of thirty members for preliminary treatment of these two questions. S. Cannizzaro was finally also on it, whose animated speech, in justice, was met by general approval. In the second session of the Congress, September 4, the commission reported the resolution it had worked out, of this content: It is decided to take a different understanding of molecules and atoms, considering as a molecule the amount of a substance entering a reaction and determining physical properties, and considering as an atom the smallest amount of a substance included in a molecule. Further it reached an understanding about equivalents, considered as empirical, not depending on the understanding about atoms and molecules. On a vote on this resolution, most raised their hands. Who was against it? Timidly one hand was raised and then lowered. The result was unexpectedly unanimous and important. Understanding the difference between atoms and molecules, chemists of all countries understood the principle of the unitary system. Now when the principle is understood, the consequences will not admit of the great inconsistencies.

The third session, September 5, was devoted to the question of atomic weights, chiefly carbon: whether to accept the new weight of 12 or remain with the former one of 6, until then used by almost everyone. After a long debate, at its last session, September 6, J. Dumas made a brilliant speech proposing to use the new atomic weight only in organic chemistry leaving the old for inorganic. Against this Cannizzaro spoke heatedly, showing that all should use the same new atomic weight. There was no vote on this question, but the great majority took the side of Cannizzaro.

To this I add the remark that in all the debates there was not one unfriendly word between both parties. All this, it seems to me is full guarantee of the rapid success of the new ideas in the future. Half the chemists have already resolved not to vote against the ideas.

D. Mendeleev, Heidelberg, September 7, 1860.

Weltzien opened the meeting on the morning of September 3 with a short address of welcome.[11] He then asked Bunsen to take the chair. Bunsen declined and the assembly elected Weltzien the presiding officer for the first session. Kekulé, Roscoe (replaced by Odling in the third session), Strecker, Wurtz, and Shishkov were selected secretaries. A motion was made by

[7] ENGLER, KARL, "Vier Jahrzehnte chemischer Forschung unter besonderer Rücksicht auf Baden als Heimstatte der Chemie," pp. 346–55, in "Festgabe zum Jubilärum der vierzigjahrigen Regierung Seiner Königlichen Hoheit des Grossherzogs Friedrich von Baden," Karlsruhe, 1892.

[8] ANSCHÜTZ, R., *op. cit.*, Anlage 8, 671–88.

[9] Moigno is not listed by Wurtz as registered at the meeting. François Napoleon Marie Moigno (1804–84), Jesuit, mathematician, friend of Boussingault and Dumas, was one of the foreign correspondents of *Chemical News* from its beginning to about 1870. Grimaux describes Moigno as an intelligent commentator, capable of appreciating the great value of the work of Laurent and Gerhardt in opposing the dualistic theory held by the majority of the French school in the period 1846–56. See ÉDOUARD GRIMAUX, "Charles Gerhardt, sa vie, son oeuvre, sa correspondance," 1900, p. 190.

[10] For information about this letter and for its translation from the Russian I am indebted to Professor Henry M. Leicester of the College of Physicians and Surgeons, San Francisco, California. The letter was published by B. M. Menshutkin in "Chemistry and the Way of its Development," Academic Science Press, Moscow and Leningrad, 1937, p. 192.

[11] A translation of this address is given in *Chymia*, I, 163–4 (1948). For an account of the confusion in the writing of formulas, etc., that led Kekulé, Weltzien, and Wurtz to call this meeting, the reader is referred to the article in *Chymia*, "Carl Weltzien and the Congress at Karlsruhe," pp. 153–69.

Kekulé that a committee be appointed to prepare the questions to be discussed. Kekulé then spoke on the topics to be considered by the committee. Erdmann insisted that the questions presented to the assembly for deliberation be concerned not with points of doctrine, but with form. After remarks by Fresenius, Kekulé, Wurtz, Boussingault, and Kopp the first session of the Congress ended.

The committee met at eleven o'clock the same morning. Among those taking part in this first meeting of the committee Wurtz mentioned H. Kopp (chairman), Cannizzaro, Kekulé, Strecker, Wurtz, Fresenius, Erdmann, Béchamp, and Shishkov. Kopp summarized the discussion and formulated the first question:

(1) Shall a difference be made between the expressions "molecule" and "atom," such that a molecule be named the smallest particle of bodies which can enter into chemical reactions and which may be compared to each other in regard to physical properties, atoms being the smallest particles of those bodies which are contained in molecules?

Fresenius now called attention to the expression "compound atom," which, he said, implied a contradiction. His remarks led to the second question:

(2) Can, perhaps, the expression "compound atom" be suppressed and replaced by the expression "radical"?

Kopp then introduced the discussion of the term equivalent and the third question to be presented for deliberation by the Congress was stated:

(3) The concept of equivalent is empirical and independent of the concept of molecule and atom.

Erdmann followed Kopp as chairman of the committee. There was some discussion on notation but no agreement on a question was reached. The committee adjourned.

At the beginning of the session of September 4 Boussingault was elected the presiding officer. After thanking the Congress for the honor that had been shown him, he made a few remarks on the questions to be submitted pointing out that they united the old chemistry with the new, but adding: "There is no chemistry which is old, there are only old chemists." Strecker read the questions for the committee, and Kekulé spoke at length on Question 1, and was followed by Cannizzaro, and by Wurtz who thought that this question might be reserved for further deliberation.

Miller, speaking on the second question, wished to drop the term, "compound atom," since there existed only atoms of elements. Opinions which differed widely were expressed by others and no agreement could be reached. The meeting adjourned. It is to be noted that in the report of Wurtz as given by both Engler and Anschütz there is no statement that the Congress passed the resolution on the clarification of the term equivalent (see letter of Mendeleev). In the report in *Le Moniteur Scientifique*, however, it is stated that the Congress voted to accept the distinction between atom and equivalent.

A second meeting of the committee, again with Kopp as chairman, followed the second session of the Congress. Kekulé spoke again on the topic of notation, followed by Cannizzaro. Kopp found it necessary to caution the speakers to avoid matters of theory and to confine their remarks to the topics decided upon by the committee. Many, however, agreed with Erdmann's comment that it is urgent to adopt a notation such that the symbols will represent a definite value in all formulas. Kopp then introduced the problem of atomic weights and their representation by symbols and proposed the following question to be put before the Congress: Is it desirable to bring chemical notation into conformity with the recent advances in the science by doubling a certain number of atomic weights?

Carl Weltzien

Later the committee met again on Tuesday with Dumas as chairman. Kekulé continued the discussion of the question offered by Kopp. Strecker made a proposal to adopt in principle the notation based on atoms. Dumas called attention to the actual confusion existing in chemistry, which, he said, must not be prolonged because of its effect on the teaching of the subject. He advocated a return to the atomic weights of Berzelius. Wurtz was happy, he said, that Dumas had brought up this subject of the atomic weights and notation of Berzelius, as he (Wurtz) was not in favor of the adoption of all the atomic weights of Gerhardt, since recent advances in experimental chemistry should be taken into account. After further discussion the committee accepted the question and voted to leave the wording of it to the bureau (the president and secretaries). Wurtz

in his report on the Congress gave no details about the discussion of the other two questions placed before the Congress at its third and last session.

The Congress met September 5 with Dumas in the chair. Dumas proposed the election of two vice-presidents. Will and Miller were elected and took their seats at the president's table. The secretaries then read the questions, the wording of which had been decided upon by the bureau:

(1) Is it desirable to bring chemical notation into harmony with advances in the science?

(2) Is it expedient to adopt anew the principles of Berzelius as they are concerned with notation, with some modifications?

(3) Is it desirable, by means of particular signs, to differentiate the new chemical symbols from those generally in use for fifty years?

Cannizzaro spoke against Question 2. This speech is written out in full in the record left by Wurtz. It is the celebrated address of the Congress in which Cannizzaro shows the great service which Gerhardt had rendered the science in basing his system of molecular weights on the theory of Avogadro and Ampère.[12] He speaks of the importance of the work by Dumas on vapor density determinations, of the value of the reasoning of Dumas' student Gaudin, and finally of Gerhardt's use of Dumas' work. Cannizzaro then explains the value of Avogadro's principle and shows that the system of Berzelius does not take it into account. This is followed by a discussion of the work of Deville on vapor densities as showing dissociation at elevated temperatures. He concludes:

> Therefore, gentlemen, I propose to accept Gerhardt's system and thus to consider the changes in atomic weights of a number of metals as these become necessary. If in regard to a new system on such a basis we shall not be able to reach an agreement, we shall at least prevent the passage of a contrary judgment. No matter what you do you will not be able to prevent Gerhardt's system from daily winning new adherents. Today already it has been recognized by the majority of young chemists who have participated actively in the progress of this science. Let us therefore pass an agreement to prevent misunderstanding which, no doubt, would be caused by the simultaneous application of old and new formulae, and let us use, therefore, the crossed-through symbols for the new doubled atomic weights.

Many speakers followed Cannizzaro. Because of the diverse opinions expressed, Erdmann took the position that on questions of principle, such as were involved, no vote could be taken and that every scientist must be allowed full freedom. In this view he was supported by Wurtz, Kopp, and Boussingault. Odling then spoke against the use of barred symbols (implied in Question 3). Dumas put the question of the use of such symbols before the Congress and the assembly voiced the wish that henceforth those atoms, the atomic weights of which had been doubled, should be denoted by crossed-through symbols. With this resolution the Congress ended except for a short speech by Dumas in which he expressed the gratitude of the members to the originators of the meeting and to his Highness, the Grand Duke of Baden, whose hospitality they had enjoyed.

There is one important incident of the Congress that is not reported by Wurtz. Lothar Meyar speaks of it in a letter to Kekulé and has included it in his remarks on Cannizzaro's paper, "Sketch of a Course of Chemical Philosophy," published in No. 30 of Ostwald's "Klassiker der Exakten Wissenschaften."[13] At the close of the meeting Angelo Pavesi, professor of chemistry in the University of Pavia and friend of Cannizzaro, distributed pamphlets of a paper written by Cannizzaro, and published it in 1858 in Volume VII of *Il Nuovo Cimento*, a journal edited by Piria as the organ of the University of Pisa. Lothar Meyer read the pamphlet on the return journey to Breslau and reread it later, and he says of it: "It was as though the scales fell from my eyes, doubt vanished, and was replaced by a feeling of peaceful certainty."[14]

Wurtz states that about 140 chemists attended the meeting but he listed in alphabetic order 127 names. I have rearranged the list of Wurtz by countries:[15]

Germany (57): Babo, Baeyer, Becker, Beilstein, Bibra, Boeckmann, Braun, Bunsen, Carius, Casselmann, Clemm, Erdmann, Erlenmeyer, Fehling, Finck, Finckh, Fresenius, Geiger, Gorup-Besanez, Grimm, Guckelberger, Gundelach, Hallwachs, Heeren, Heintz, Hirzel, R. Hoffmann, Keller, Knop, Kolbe, Kopp, Kuhn, Landolt, Lehmann, Ludwig, Mendius, L. Meyer, Mulhäuser, Müller, Naumann, Nessler, Neubauer, Petersen, Quincke, Scherer, Schiel, Schmitt, Schneyder, Schroeder, Schwarzenbach, Seubert, Strecker, Streng, Weltzien, Will, E. Winckler, Zwenger.

France (21): Béchamp, Boussingault, Dumas, Friedel, Gautier, Grandeau, Jacquemin, Ch. Kestner, LeCanu, Nicklès, Oppermann, Persoz, Reischauer, Riche, Scheuer-Kestner, Schlagdenhauffen, Schneider, Schützenberger, P. Thénard, Verdet, Wurtz.

Great Britain (18): Abel, Anderson, Apjohn, Crum-Brown, Daubeny, Duppa, Foster, Gilbert, Gladstone, Griffith, Guthrie, Miller, Noad, Normandy, Odling, Roscoe, Schickendantz, Wanklyn.

Austria (7): Folwarezny, Hlasiwetz, Lang, Lieben, Pebal, Schneider, Wertheim.

Russia (7): Borodin, Lesinskiĭ, Mendeleev, Natanson, Savich, Shishkov, Zinin.

Switzerland (6): Bischoff, Brunner, Marignac, von Planta, Schiff, Wislicenus.

Belgium (3): Donny, Kekulé, Stas.

Sweden (3): Bahr, Berlin, Blomstrand.

Italy (2): Cannizzaro, Pavesi.

Mexico (1): Posselt.

Portugal (1): Carvalho.

Spain (1): deLuna.

[12] This is the contribution of Auguste Laurent adopted by Charles Gerhardt and discussed in Vol. IV of his "Traité," **1856**. See A. LAURENT, *Ann. de Chim. et de Phys.* [3], **18**, 294–7, (1846); "Méthode de Chimie," **1854**, pp. 79–97. W. ODLING, "Chemical Method," translation of Laurent's book, **1855**, pp. 62–85.

[13] The paper has been translated into English and published as Alembic Reprint No. 18.

[14] Ostwald's "Klassiker," No. 30, p. 59. Lothar Meyer's treatise, "Modern Theories of Chemistry," in which the ideas of Cannizzaro are fully developed, was begun in 1862. The publication of this book in 1864 made Meyer's reputation in the world of chemistry.

[15] ANSCHÜTZ (*op. cit.*, p. 673) rearranged the list of Wurtz according to countries and the cities from which the chemists came. He omitted the name of Hermann Kolbe and placed J. H. Gilbert under Sweden. Joseph Henry Gilbert worked with John Bennet Lawes at the Rothamsted agricultural experiment station near Harpenden in Hertfordshire, England.

If the training in chemistry of the majority of those attending the Congress is noted, one is impressed by the influence of Heidelberg, Giessen, and Paris in the development of chemistry from 1820 to 1860. About 20 per cent of the list of Wurtz had studied at Heidelberg, the majority under Bunsen. In his teaching, Bunsen, like his predecessor at Heidelberg, Leopold Gmelin, emphasized facts, but neither was averse to a consideration of new hypotheses and both encouraged independent thinking. Liebig's great influence as a teacher in the period 1824 to 1853 accounts for the next largest group. Two of the originators of the Congress, Kekulé and Wurtz, had begun at Giessen. About 16 per cent of the assembly came to Karlsruhe already converted to the unitary system with its distinction between equivalent and atom, between atom and molecule, so clearly set forth by Laurent, and converted also to the new type theory which had been developing since 1846 out of the speculations of Laurent and the experimental work of Hofmann, Williamson, Wurtz, and Frankland. This so-called radical minority had either studied in Paris after 1846, and thus had come under the influence of the teaching of Laurent and Gerhardt or in later years of Wurtz, or they were followers of Kekulé who had attended Gerhardt's conferences in Paris in 1851–52.

The conservative chemists far outnumbered this minority group. I have not been able to discover a difference between the average age of the conservatives and the average age of the radicals. The average age of 89 of the 127 recorded is thirty-nine years. Incidentally the oldest chemist (65) at the Congress was Charles G. B. Daubeny of Oxford; the youngest (22) were Frederich C. Beilstein, then working at Göttingen, and Alexander Crum-Brown from Edinburgh.

To evaluate the effect of the Congress on the development of chemistry in the countries from which the majority of the chemists came is difficult. There is no doubt, however, that the effect was greatest in Germany and least in France. The great effect in Germany, particularly in organic chemistry, may have been due in part to the advertisement of Gerhardt's treatise and the textbook of Kekulé, based upon it, received at the meeting through conversation during the long periods when the assembly was not in session; and there is no question that the publication of Lothar Meyer's book in 1864 won over a large majority of the German chemists to the new atomic weights. On the other hand, Wurtz and Friedel for the next twenty-odd years struggled against the strongly intrenched conservatives in Paris, like Berthelot, Debray, Deville, and Frémy, who continued to follow the system of Berzelius, as it had been modified by Gay-Lussac and the elder Thenard and who continued to write formulas based on equivalents.[16] From 1855, the year of the publication by William Odling of Laurent's "Méthode de Chimie," the majority of the leading chemists of Great Britain, with the exception of Hofmann and a few of his students, had adopted the new system of Laurent and Gerhardt. The published papers of Odling[17] and Williamson show this. The situation in Russia resembles in some respects that in Great Britain; Laurent's "Méthode" and Gerhardt's "Traité" were widely read.

The Congress at Karlsruhe, in my opinion, is the most important event in the development of chemistry in the middle of the nineteenth century. There may be a question, however, as to how important it was. If Lothar Meyer had not attended the meeting would he have begun "Modernen Theorien" in 1862 and published it in 1864? If the atomic weights of carbon, oxygen, sulfur, silver, and the alkali metals had not received their present values early in the 1860's would Lothar Meyer and Dmitri Mendeleev have worked out the periodic table of the elements in 1869? I do not think so. But I should like to remind the reader that in the history of science, as in any other history, all the facts can never be known, and the facts which are recorded by individuals of the period are colored by the background and personality of those particular individuals. Moreover the historian is after all only an interpreter of past events and his slant on a particular period is influenced by his own interests and also by his own attitude toward people and the subject about which he is writing.

ACKNOWLEDGMENT

The author wishes to thank the staff of the Stanford University Libraries and the staff of the John Crerar Library for their courtesies to her. Especially does the author thank Robert F. Sutton, Curator of the Edgar F. Smith Collection at the University of Pennsylvania, for his help in locating material on those who attended the Congress. Part of the expenses of gathering the material was met by a Carnegie grant-in-aid given the author by the University Council on Research of Tulane University.

[16] It is almost impossible to form an opinion as to what was Dumas' stand on the new trends in chemistry, for even though he always sided with the conservative members of the French Academy of Sciences, he protected, sometimes encouraged, the adherents of Laurent and Gerhardt, as in the matter of the teaching of Wurtz and Naquet.

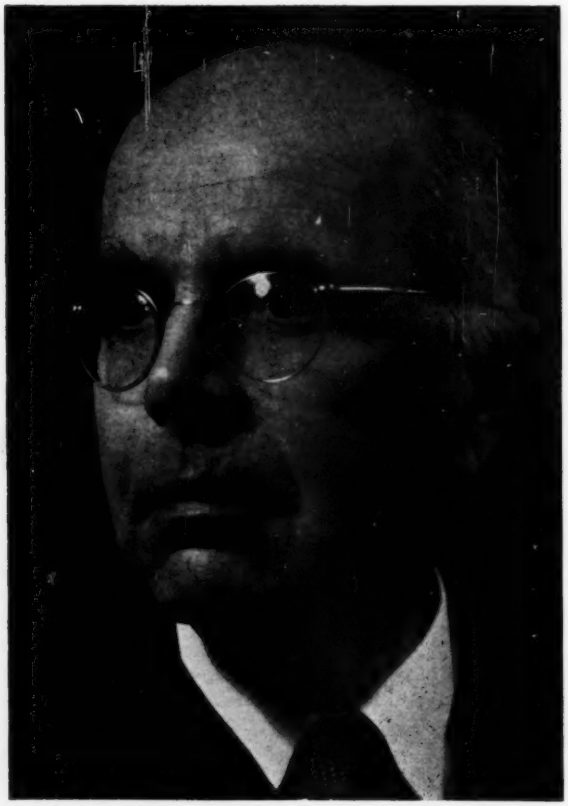
[17] *Phil. Mag.* [4], **13**, 423–39, 480–96 (1857); *ibid.*, **16**, 37–45 (1858); *J. Chem. Soc.*, **11**, 112 (1858); *Chem. News*, **8**, 147–52 (1863).

KARL FREUDENBERG

RALPH E. OESPER
University of Cincinnati, Cincinnati, Ohio

THE Chemisches Institut of the University of Heidelberg has been headed by Leopold Gmelin (1817–53), Robert Bunsen (1853–88), Victor Meyer (1889–97), Theodor Curtius (1898–1926), and (since 1926) by Karl Freudenberg. When the latter was congratulated on his selection to this high office, he modestly replied: "I am quite aware of the great honor that has come to me, but I am equally conscious of the great responsibility I have assumed."

Karl Freudenberg was born at Weinheim, Baden, on January 29, 1886. He received his training at Bonn (1904–07) and then under Emil Fischer at Berlin (1907–10) where he received the doctorate in 1910. He stayed on in Fischer's laboratory, studying the linking of gallic acid and similar materials, which occur in plants. After *m*-digallic acid was prepared in pure form, and its supposed identity with the vegetable tanning material gallotannin was disproved, one of these tannins (pentagalloyl glucose) was successfully produced from gallic acid and dextrose. At the same time, he observed the first indications of the wandering of ester groups (acyl migration), a topic which was later investigated by E. Fischer and Max Bergmann. In one of the natural tannins, *Hamamelis virginica*, Freudenberg found a branched new sugar, whose structure was later clarified by O. T. Schmidt.



Karl Freudenberg

Dr. Freudenberg became *Privatdozent* at the University of Kiel in 1914; the habilitation essay dealt with the spatial arrangement of the atoms of lactic acid. Four years of military service followed immediately. He then returned to Kiel to begin his teaching career. Another class of vegetable materials, the catechins, was opened up. At the suggestion of R. Willstätter, he moved to Munich, where he again habilitated (1920). Here he entered the field of high-polymer natural products and interpreted cellulose as being made up of chains of similarly linked glucose units, a position that at the close of the debate, which was then just beginning, was proved to be correct.

As *Extraordinarius* in organic chemistry at Freiburg, under H. Weiland (1921–22), and as *Ordinarius* at the Technische Hochschule in Karlsruhe (1922–26), Professor Freudenberg continued his researches on tannins and brought the study of catechin to a close (synthesis of catechin from cyanidine (1925) in collaboration with O. T. Schmidt). At the same time the studies of the sugars were carried further. Some of the results were: elucidation of diacetone-glucose and other acetone sugars, synthesis of disaccharides, and discovery of the cyclic acetates of sugars. A new field of interest was lignin, the binding material of wood. It was considered to be a phenylpropane derivative with many ether linkages.

The headship at Heidelberg brought with it greatly increased numbers of advanced students, *i. e.*, collaborators in Professor Freudenberg's researches, and accordingly the scope of his fields of interest was extended. Together with Werner Kuhn,[1] he put the configuration theory on a broad basis and the steric relation of the amino acids and the α-halogeno fatty acids to the hydroxy acids was definitely established. The shift rule of the optical rotatory power, which had already been set up in the Freiburg period, was given a firm theoretical foundation and extended to sugars and polysaccharides. The significance and limits of optical superposition were characterized. At this time he and Kuhn had a capital success, in that they produced optical activity through physical means by irradiating azido-propionic acid with circularly polarized short-wave light. The kinetics of the degradation of cellulose were intensively

[1] OESPER, R. E., J. CHEM. EDUC., **27**, 416 (1950).

studied from both the theoretical and practical standpoints. These studies, along with the discovery and synthesis of methylated cellotriose, confirmed the statement of 1921 that cellulose is a chain molecule made up of like glucose units linked together. Starch, the other great polysaccharide of glucose, was the next center of interest. The branching positions of the starch molecule were determined. The remarkable starch degradation products, the Schardinger dextrins which result from bacterial action, were found to be ring-shaped saccharides, and a third example was added to the ones previously known.

Insulin and blood-group stuffs are instances of the many single subjects that have been investigated in Freudenberg's laboratory. Sugars, glucosamines, and amino acids have been separated with the aid of ion exchangers. The laborious study of lignin, which at first did not offer any obvious point of attack, advanced steadily and in the last years has become the center of most of the attention. Steady progress has brought the conviction that this natural product is likewise constructed according to an orderly principle, though to a limited extent. Recently, Professor Freudenberg and his co-workers have successfully achieved the synthesis of lignin through the simultaneous dehydrogenation and polymerization of coniferyl alcohol. This accomplishment removed the obstacles which hitherto have impeded the task of unraveling the constitution of this important natural product.

In addition to the long list of papers which bear Karl Freudenberg's name, and which have made his name a household word in organic circles, he has published in book form: "Chemie der natürlichen Gerbstoffe," Berlin, 1920; "Tannin, Cellulose, Lignin," Berlin, 1933; "Stereochemie," Vienna, 1933; "Organische Chemie," 7th edition, Heidelberg, 1950.

His honors include membership in the learned academies of Heidelberg, Munich, Göttingen, Helsinki, Uppsala, Lund, Halle. Professor Freudenberg has been Visiting Professor at the University of Wisconsin and has recently completed a term as Rector of the University of Heidelberg.

LARGE CRYSTALS OF MONOCLINIC SULFUR

MILTON G. WOLF
James Madison High School, Brooklyn, New York

In a pamphlet on sulfur which I read a couple of years ago there was included a table which listed several solvents for sulfur, among which, strange at it appeared to me, was olive oil.

The following question arose in my mind at the time: Suppose olive oil is saturated with sulfur at the highest temperature reported, 130°C., and then cooled, would not monoclinic sulfur crystallize out between 114.5° and 96°C., since this is the stable form between these temperatures? Moreover, if the solution is cooled very slowly, would not large size crystals be obtained?

I did not act upon these thoughts until this year, and in the meanwhile have forgotten the name of the company to which I am indebted for the table of solubilities.

As a result of employing this method outlined below I obtained monoclinic sulfur crystals which are by far the largest I have seen of this form, and although the method is time-consuming by comparison with the conventional method, I feel the reward worth the effort.

PROCEDURE

Pour ground roll-sulfur into a 150-ml. beaker until it rises to a height of 1/4 in. Then add about 25 ml. of olive oil. Pour 350 ml. of olive oil into a 600-ml. beaker. Partly immerse the small beaker in the olive oil contained in the larger beaker.

Heat the large beaker gradually, all the while stirring the sulfur-oil mixture in the small beaker with a thermometer graduated to at least 130°C. Meanwhile heat a large-size test tube until it feels uncomfortably warm. When the temperature of the mixture in the small beaker reaches 130°, remove the flame and pour the oil from the small beaker into the test tube, being careful not to include any undissolved liquid sulfur. Pour the oil from the large beaker slowly into a clean dry 1-pint thermos bottle. Stopper the test tube and place it in the thermos bottle. The test tube will go in all the way to its flange without causing spillage of any oil from the thermos. Place some tissue paper loosely in the cap of the thermos and screw on the cap. Stand the thermos upright in a cabinet for at least 24 hours. Remove the test tube from the thermos. Fine, long, needle-like crystals, ranging from 1/2 to 1 in. in length, should be present.

Since rhombic sulfur is the only stable form below 96°C., these crystals upon standing a few days will be changed into aggregates of minute crystals of rhombic sulfur, although the over-all monoclinic form is preserved. This so-called crystalline shape is called a pseudomorph.

THE CLAUSIUS-CLAPEYRON EQUATION

OLIVER L. I. BROWN
Syracuse University, Syracuse, New York

Almost without exception textbooks of physical chemistry follow the original derivation of Clausius in arriving at the Clausius-Clapeyron equation for vapor pressures. The assumptions are made that (1) the volume occupied by one mol of liquid under its saturation pressure is negligible compared to the volume occupied by one mol of vapor, (2) the vapor behaves as an ideal gas, and (3) ΔH of vaporization does not change with temperature. The exact form of the Clapeyron equation

$$\frac{dP}{dT} = \frac{\Delta H}{T(V_g - V_L)} \tag{1}$$

is then readily converted to the Clausius-Clapeyron equation

$$\ln P = -\frac{\Delta H}{R}\left(\frac{1}{T}\right) + \text{constant} \tag{2}$$

This equation predicts that $\ln P$ will be a straight line when plotted against $1/T$ and that the slope will be $-\Delta H/R$. It is usually pointed out that the assumptions limit the use of this equation to low pressures. It then becomes impossible to explain the experimental fact that the plot of $\ln P$ versus $1/T$ is frequently very nearly linear up to the critical point, even though all three of the assumptions made are evidently no longer valid.

It is the purpose of this paper to show a simple alternative derivation which avoids these difficulties and which shows that linearity of $\ln P$ versus $1/T$ does not require that ΔH be independent of temperature except in the limit of zero pressure. This derivation also shows that even at one atmosphere pressure a simple correction should be applied in calculating ΔH from the slope of the straight line.

The derivation is as follows:

$$(V_g - V_L) = V_g\left(1 - \frac{V_L}{V_g}\right) = \frac{zRT}{P}\left(1 - \frac{V_L}{V_g}\right) \tag{3}$$

where z, the compressibility coefficient, is a function of temperature and pressure, and varies from unity at zero pressure to about 0.2 or 0.3 at the critical point. Substituting the right-hand member of equation (3) into equation (1) we obtain

$$\frac{dP}{dT} = \frac{P\ \Delta H}{zR(1 - (V_L/V_g))T^2} \tag{4}$$

Then

$$\frac{dP}{P} = \frac{\Delta H\, dT}{zR\,(1 - (V_L/V_g))T^2} \tag{5}$$

or

$$\frac{d \ln P}{d\,(1/T)} = -\frac{\Delta H}{zR\,(1 - (V_L/V_g))} \tag{6}$$

Equation (6) is exact, but contains three terms which vary with temperature. Now if $\ln P$ is linear with $1/T$ with slope B, that is, if

$$\ln P = B(1/T) + \text{constant} \tag{7}$$

it follows that

$$\Delta H = -zBR(1 - (V_L/V_g)) \tag{8}$$

Since z varies from unity to 0.2 or 0.3 as the pressure increases along the saturation curve from zero to the critical pressure, and since $(1 - (V_L/V_g))$ varies from unity at zero pressure to zero at the critical point, it follows that linearity of $\ln P$ versus $1/T$ demands that ΔH vary from $-BR$ at very low pressures to zero at the critical point. At pressures near one atmosphere ΔH values calculated as $-BR$ are usually several per cent too large. Multiplication by the z factor will restore them to agreement with the calorimetric values of ΔH if the equation $\ln P = B/T + A$ really fits the data, since the term $(1 - (V_L/V_g))$ will still be essentially unity at one atmosphere pressure, except in the case of extremely low boiling liquids.

The recent measurements of Friedman and White[1] on the vapor pressure of liquid nitrogen serve as an excellent example of a case in which the $\ln P$ versus $1/T$ plot is practically linear up to the critical point. The ΔH of vaporization calculated from the vapor pressure curve is tabulated by these authors at even temperatures and found to vary from 1320 calories per mol at the boiling point to 280 calories at 1° below the critical temperature.

It should be noted that equation (6) is perfectly general and without approximations. It shows that the slope of the tangent to the plot of $\ln P$ versus $1/T$ at any point when multiplied by $-zR(1 - V_L/V_g))$ will give the ΔH of vaporization at that temperature. Here again the z term is increasingly important with increasing pressure. The term involving volumes makes ΔH zero at the critical temperature since then V_L will be equal to V_g.

The z factor is, to a good approximation, a general function of reduced temperature and reduced pressure so that where critical data are available it is readily possible to calculate this quantity even if P-V-T data are not available for the region of interest. The Berthelot equation of state is also readily solved for PV_g/RT, which is the z factor.

The alternative derivation of the Clausius-Clapeyron equation suggested here is certainly not too difficult for the beginning student in physical chemistry. By postponing the three approximations to the last step,

[1] Friedman, A. S., and D. White, *J. Am. Chem. Soc.*, **72**, 3931–2 (1950).

the student can obtain a clearer idea of how these approximations enter into the final result. For instance, it will be found that at low pressures the assumption of ideal gas behavior introduces more error than the assumption of negligible liquid volume, but that at higher pressures this situation is reversed. Only in the limit of extremely low pressures does the assumption of the constancy of ΔH with temperature enter at all.

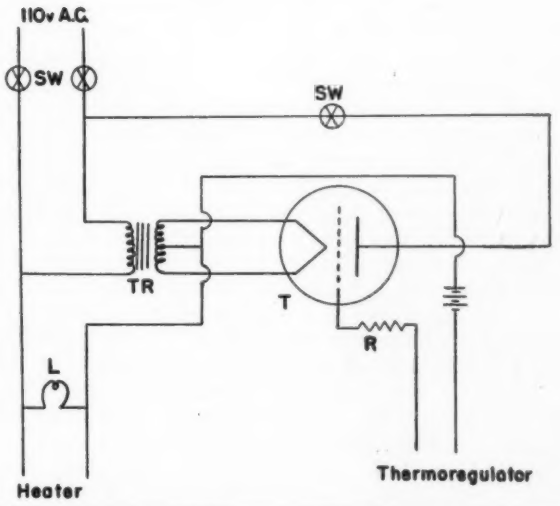
A SIMPLE ELECTRONIC RELAY

JOHN J. PITHA
Michigan State College, East Lansing, Michigan

THE obvious disadvantages to the mechanical-type relay is apparent to everyone who has ever experienced the annoyance of "sticking," "chattering," or "sparking" that usually accompanies their operation. The electronic type relay, with its absence of moving parts, is the answer to the problem of elimination of the above-mentioned annoyances. Some thyratron control circuits are to be found in the literature[1, 2] but for the most part these specify tubes of foreign manufacture, or a type no longer manufactured. Since there were no tube characteristics given, it is not easy to substitute available thyratron tubes. Visitors to these laboratories have expressed interest in the electronic relays they have seen in operation here, and for that reason it is thought that the wiring diagram, along with a list of parts required for the relay might be of general interest. The list of parts required is given in the table, and the circuit diagram is given in the figure.

The component parts of the apparatus need not be mounted in the cabinet suggested, but may be mounted on a board. If the relay is to be used in the vicinity of a constant temperature water bath, however, it probably will be desirable to enclose the entire electrical assembly. The only caution to be exercised in putting the component parts of the system together is to be certain that the banana jacks are insulated from the metal cabinet. This caused some difficultly until the nature of the problem was realized.

The G.E. Thyratron #3C23 was chosen because it was available surplus at very low cost, and had a power rating sufficient to do the job for which it was intended. This tube is rated at 1000 volts and 1.5 amperes, but since the maximum current passed is never to exceed 1.5 amperes, the maximum load that can be controlled is 165 watts at 110 volts. It has been found that a 125- or a 150-watt immersion heater will maintain the temperature of a normal size water bath up to a temperature of about 30°C. with no difficulty. For higher temperatures, a second heater "on" all the time, used in conjunction with the controlled heater, gives satisfactory results. Of course it is possible to actuate a mechanical relay with the current passed by the thyratron tube, and so handle larger loads, but the limiting factor in the ease of control again becomes the mechanical relay.



Parts List for Thyratron Control Unit

T	G.E. Thyratron Tube #3C23
Tr	Stancor Filament Transformer #P3024
R	1000-Ohm, 1-watt resistor
L	Neon panel-light assembly
SW	D.P.S.T. Toggle switches (two)
	Cabinet, with chassis, Bud #CU1990
	Battery, 4.5 volt
	4-Prong, type RS tube socket
	2-Prong female receptacle with separate mounting plate
	2-Prong male plug
	Banana plugs and jacks (two pair)

[1] ZABEL, R. M., AND R. R. HANCOX, *Rev. Sci. Inst.*, **5**, 28–9 (1934).

[2] SCHWENK, H. S., AND D. E. NOBLE, *J. Phys. Chem.*, **41**, 809–10 (1937).

THE FUTURE OF HIGH-SCHOOL CHEMISTRY

ELBERT C. WEAVER
Phillips Academy, Andover, Massachusetts
HANOR A. WEBB
George Peabody College for Teachers, Nashville, Tennessee

THE logic of this article is based on a major premise: *modern wars are won by the nations that have the best scientists.* The minor premise is: *our nation with its allies is engaged in a small but bitter war,* possibly the prelude for a larger war. Even if something called "peace" should blanket the planet, a period of international tension may last for years.

The conclusion to this syllogism is: *the program for training scientists in our nation must be made effective, and kept that way.* Then we shall have a reservoir of technically trained people, ready to serve in the defense of our country, and indeed in the defense of freedom anywhere in the world.

This article deals with only one phase of the training program for future scientists—that of chemistry in the high school. The problems of other sciences, however, are equally pressing. One example is the paradox of declining student enrollment in physics while the need for physicists, and the general understanding of physical principles, becomes ever more urgent. Another is the continuing preoccupation of high-school biology with its own taxonomy although the recent advances in biology cry for a broadened approach to the subject.

If our nation is to be defended in the future, the training of many of our chemists must start in the high schools now. Certain emphases are needed to make the high-school courses strong foundations for military and civilian needs of a technical nation. The most obvious of these emphases are:

(1) *Earnest, intensive laboratory work in every high-school chemistry course.* Scanty experiences in a poorly equipped laboratory, or the haphazard use of a well equipped laboratory, must be replaced by a serious program. There is no other way to develop that coordination of hand and mind that every technician in industry must possess. There is no better way to develop observation and resourcefulness. The "feel" of apparatus comes only by experience.

Informal, unpublished investigations of recent date have revealed a surprising number of chemistry students who do not perform a single experiment in a year. Some schools have closets full of chemical equipment, but these closets are never unlocked. It is amazing that so many chemistry teachers can avoid the exertions of laboratory work without protest from their principals.

In certain areas of our nation increased budgets for laboratory equipment and supplies are needed. In fact, one measure of a school's participation in the Civil Defense Program is the size of the laboratory budget, coupled with the liberal use of these supplies.

(2) *Enrichment of classroom instruction in chemistry, far beyond the text.* Charts, specimen kits, bulletins, booklets, and other types of free and low-cost materials should be on hand in quantity. Industry produces material of this nature in abundance. The Packet Service of the National Science Teachers Association (1201 Sixteenth Street, N.W., Washington 6, D. C.) is an extensive distributor, and the clipping service of the Association's magazine, *The Science Teacher,* brings new material to the teacher for the cost of a three-cent stamp. Many of these teaching aids are related directly to chemistry.

A recent comprehensive list for many teaching areas, including science, is "Free and Inexpensive Learning Materials," Division of Field Surveys, George Peabody College for Teachers, Nashville, Tennessee; price, 50 cents.

Administrators should look into the "enrichment habits" of their chemistry teachers. An instructor who accumulates and uses a generous supply of free and low-cost teaching aids is probably among the more alert members of his profession.

(3) *An ample library of books on chemistry.* These should be selected for their up-to-dateness and their appeal to the interest of high-school students. The chemistry bookshelf should be ever growing, with several new volumes added each year. Considering the reading abilities of students, some of these books should be simple; the simplest we know is "Picture Book of Chemistry" by J. S. Mayer (Lothrop, 1950). Of proved interest is "First Chemistry Book for Boys and Girls" by A. P. Morgan (Scribner, 1950). No chemistry library should be without the new edition of "Crucibles—the Story of Chemistry from Ancient Alchemy to Nuclear Fission" by Bernard Jaffe (Simon and Schuster, 1948). Other titles may be found in the annual book list of THIS JOURNAL.

Every important chemical industry has published popular descriptions in book form. These titles, as they have appeared since 1945 (for some prewar descriptions of industry are obsolete), and as they are published in the future, may be found readily in the well-classified *Cumulative Book Index* that appears monthly. The titles, with brief descriptive annotations, are also given in *Publisher's Weekly.* These lists

are in all town and city libraries of fair size, and in some school libraries as well.

(4) *Regular attention to current progress in chemistry.* The high-school chemistry teacher has an obligation to keep well informed on chemical and educational progress. This is his professional duty. Suitable aspects of new developments should be brought to the attention of his classes. Some of this information is exciting headline news—such as the discovery of the new synthetic elements, californium and berkelium, by Seaborg and his associates. Some of it is industrial current events—such as the news of new synthetic fibers, new silicones, jet fuels, and the nature of napalm, a military weapon that exceeds Greek fire a thousand to one as a terror of war. Some of it is domestic—such as the increasing number of synthetic detergents used by women in their endless battle for cleanliness in the home.

Keeping up with chemistry implies the reading of periodicals. There is no lack of monthly reading matter to challenge the high-school student. *Chemistry*, a pocket-sized monthly published by Science Service, Washington, D. C., is the most specialized. Many articles of high value to the abler students appear in THE JOURNAL OF CHEMICAL EDUCATION, the organ of the Division of Chemical Education of the American Chemical Society. The teacher, of course, should be a consistent reader of THIS JOURNAL. The teacher's attention is also directed to *Chemical Industries Week* (McGraw-Hill, New York) which tells the story of progress in chemical industry as it happens. If the high-school chemistry teacher can meet professional standards in chemistry, he may become a member of the American Chemical Society, and receive weekly *Chemical and Engineering News*, a magazine carrying staff reports of chemical meetings and current information about chemical progress.

Chemistry is often included in periodicals of a more general nature. The classroom weekly, *Current Science and Aviation* (American Education Press, Columbus, Ohio), balances chemistry with biology and physics in news and background principles on the high-school level. The *Reader's Guide to Periodical Literature* and *Industrial Arts Index* are ready references to the stories of chemistry that are written for public understanding.

(5) *An adequate audio-visual program in chemistry classes.* In many teaching situations, "adequate" implies a great expansion of present film, film-strip, and slide services. Why should the social-studies teachers show all the motion pictures? An abundance of visual aids is at hand for chemistry, showing theory, industrial operations, and practical applications. It is a small school indeed, with a very old-fashioned principal, which does not have projectors and screens today.

The reader is directed to Bulletin No. 2, "Films on Chemical Subjects," in its 1949 edition and supplement. It is available from the American Chemical Society, 1155 Sixteenth Street, N.W., Washington 6, D. C.; its price, 50 cents. This pamphlet lists titles with a brief description of each film. The addresses of film libraries are also included.

(6) *A selection of topics on the basis of today's chemistry.* This will, of course, involve replacements—something new *in*, something old *out*. Some study of principles of chemistry discovered before 1850 must give way to lessons on the principles discovered after 1850, and even after 1950.

In all our history, chemistry has never affected our way of life so greatly as it does today. The experienced teacher may have to part with many favorite lecture topics as—in the new spirit—he presents more polymerization and less Arrhenius, more catalysis and less Gay-Lussac, more electrochemistry and less Dalton. It has become so important to think in terms of ions that we must modify our thinking about atoms and molecules.

(7) *A great increase in attention to organic chemistry.* A background of organic chemistry is necessary to appreciate that most significant trend in modern industry—less use of natural raw materials, and more use of synthetic products. Examples are the billions of pounds of synthetic detergents, millions of pounds of synthetic elastomers, the growing use of synthetic fibers. New organic waterproofing compounds make inorganic impregnations obsolete. Some of yesterday's inorganic topics in the high-school chemistry course must give way to organic topics, even as much of yesterday's clay crockery has been replaced by molded plastic. Classroom emphasis on conservation of our mineral chemical resources must yield time to study of the source-materials for factory-made resins, fibers, and vitamins.

(8) *Broad training for chemistry teachers.* In both research and industry, the artificial boundaries of the several sciences are crossed freely. Significant developments usually result from the labors of teams, each scientist a specialist in his own field. It is obvious that the more effective workers are those whose outlook and interest have remained broad even while the r special fields of authority became narrow.

They who have given us the antibiotics, sulfa drugs, and new pesticides are straddling the fields of chemistry and biology. Those engaged in nuclear research must embrace both chemistry and physics. The expanding field of nutrition employs chemists who double as physiologists. Progress in soil science comes from chemists who have an earthy slant. Chemical engineers are chemist-mathematicians who have a flair for solving the problems of the work-a-day world.

More than ever, today's high-school chemistry teacher needs background in other sciences. Biology, physics, and geology will help him often. His mathematics should be a bright tool, even if not extensive. Programs for the training of science teachers on this broad basis exist in many colleges; they are wholly lacking in others. High-school administrators should no longer accept the teaching services of the one-talent individuals. Progress and practical use of science in the next

generation do not deserve this handicap, whether the chief concerns at that time are of peace or of war.

(9) *Participation in the high-school guidance program.* All signs of the coming decades point to fewer workers on the farms and more workers in the factories. Using less man power, agriculture must become more efficient —hence more scientific. Industry is already making extensive use of science, and this trend will increase as our nation becomes more populous and the average life-span lengthens.

Chemistry offers either essential or helpful knowledge to countless workers in both agrarian and industrial employment. The high-school chemistry teacher, therefore, should yield to no fellow instructor in the quality of his efforts at guidance. If the spark of talent appears in any student, he should discover it. He should know the industries of his community thoroughly; he should be well informed concerning the industries of his region; he should adequately understand chemical industry throughout the nation.

Chemistry is indeed a fine vocation! It offers a satisfying level of attainment for every ability. It provides outlet for every talent—research, control, labor relations, engineering, management, sales, editing, teaching, and many others. See "So You Want To Be a Chemist" by Herbert S. Coith (McGraw-Hill, 1943); also the reprinted articles on "Chemical Vocations" from *Chemical and Engineering News* (American Chemical Society, Washington 6, D. C.).

In chemistry there is always progress—unless the individual himself selects a rut. Chemical industry is expanding, not contracting as certain industries are doing. Chemical industries know the money value of waste; hence they husband their resources in the spirit of modern conservation, and guarantee themselves decades—possibly centuries—of continued activity.

Yes, chemistry is a streamlined train to catch along this railroad we call life. Cannot the high-school chemistry teacher gather some warmth of this enthusiasm, and pass it along to spirited youngsters? It will be a pity for them to miss the train, if they would be happy in the journey!

(10) *Planning chemistry for young women.* Courses in chemistry in high school attract relatively fewer girls than boys. Texts in "household chemistry" have had scanty sale. Perhaps no strong reason for girls to be interested in chemistry has seemed to exist heretofore—but the picture has changed.

There is a great demand for young women to enter nursing—and chemistry is a part of the training of nurses. The chemical research and control laboratories of all types are in need of women as technicians, or for more expert employment. Our "lady majors" are snapped up by the clinical laboratories. Doctors and dentists need helpers who know the fundamentals of chemistry. The state and city testing laboratories sometimes prefer women for their accuracy and patience. The industries find women entirely suitable to "man" the newer instruments of analysis. Chemical knowledge is helpful to the versatile typist-secretaries who run the offices of chemical supply houses, wholesale druggists, cleaners and dyers, ceramists, food processors, morticians, dairies, college chemistry departments, and a great variety of industries.

Opportunity for women in chemistry is great. Able girls in the high school should be given this assurance by their chemistry teachers.

(11) *Adjustment to contemporary "fused science" courses.* No chemistry teacher wants *all* of the high-school students to attend his chemistry classes. He desires the competent and the interested. If he is wise, his course in chemistry will neither frighten the timid students by its reputation for difficulty, nor allure lazy students by its simplicity.

Some students in an unselected high-school group receive little benefit from a formal study of one particular science. Courses variously called "fused science," "generalized science," "integrated science," "consumer science," and so forth, have been placed in grade 12 for this group. These broad courses are offered in the high school in the spirit of general education. No wise high-school teacher will oppose them, provided they do not enroll students who should be studying chemistry.

(12) *Better psychology for chemistry teaching.* The modern high-school student simply will not perform the "grind" that marked instruction of the older days. Today's chemistry must be fun, even while it is work. The lesson of Tom Sawyer's whitewashing crew should not be forgotten. If the high-school chemistry teacher does not already know many interesting stories and incidents, he should find (or even invent) them.

Modern high-school chemistry must be dramatized. Tell of a hypothetical (unhappily, perhaps real) enemy working against time to build his chemical stockpile higher than our own. Then every strategic chemical acquires a grim glamour. Tell about Germany's chemical preparation for World War I, waiting for Fritz Haber to perfect the fixation of nitrogen from the air. Tell of our own nation's frantic struggles to make 100-octane gasoline and synthetic rubber, undertaken belatedly after World War II had begun.

Require students to report on the massive equipment, designed with consummate skill, that wrests chemical raw materials from natural deposits. Describe the far-flung system of transport by land and sea; the amazing efficiency of chemical processing; the astonishing diversity of uses of finished chemical products.

Do not fail to study the community's local chemistry by first-hand visits and lessons. Collect specimens of all types of local objects that have chemical interest. Prepare displays of the products of local factories, most of which are using some chemical process. Count the chemicals on the grocers' shelves; note that drug stores are full of chemicals, many of them identical with those of your laboratory, but with different uses.

Motivate your chemistry course by the helpful understanding of certain home problems. Include a strong vocational slant. Assert that an understanding of chemistry makes people aware of the opportunities of

their environment, and they become more resourceful. They become better consumers, and richer in good things. Develop all possible appreciations of this type that occur to you. Remember that effective education causes people to think, feel, and act intelligently. Watch for these results among your students.

Finally, dramatize your teaching task to fire your own spirit. You are engaged in the battle against ignorance. You are building a stockpile of vital information, and a background for intelligent action on the part of the next generation. You are helping men and women to survive in life's battles because you taught them as boys and girls to observe and adjust to nature. Take any analogy you wish; apply it; believe in it!

It is your hope, and ours, that the anxieties of a nation geared for war will eventually relax. Then you will have a sense of having done your part in the national effort. The victories of peace are then to be won, and they are no easier than those of war. Through your teaching, you share in all such victories.

NIELS BJERRUM

RALPH E. OESPER
University of Cincinnati, Cincinnati, Ohio

COPENHAGEN, which in a chemical historical sense is synonomous with Denmark, has long been the home of famous chemists. Since the days of Oersted its specialty has been men who work in the borderland between physics and chemistry. The present dean of Danish physical chemists is Niels Bjerrum, whose name and accomplishments are known the world over.

Born on March 11, 1879, at Copenhagen, he studied at the University of Copenhagen, where he took his doctorate in 1908 under S. M. Jorgensen. His teaching has been in two institutions, his alma mater and the Royal Veterinary and Agricultural College of Copenhagen, where he was professor of chemistry from 1914 until his retirement in 1949. His 70th birthday was honored by the issuing of a volume of "Selected Papers,"[1] which gives a cross section of his many and varied publications. The divisions of this book: History of Chemistry; Chemical Physics; Physical Chemistry; Inorganic Chemistry, indicate the main lines of his interests.

Bjerrum's historical articles are "reviews of the development of chemistry seen with the eyes of one of our outstanding chemists." Though few in number, they are valuable because of his keen insight.

His work in chemical physics came fairly early (1911–14). These papers dealt with the relations of thermodynamic data to other values which could be secured spectroscopically. He used both classical mechanics and the quantum theory in these papers which are concerned with the constitution and the optical and thermal properties of molecules.

Physical chemistry makes up the bulk of his publications. The idea of complete dissociation of strong electrolytes was advanced in 1909 and developed in subsequent papers, where interionic forces, activity coefficients, and studies of ionic distribution coefficients were given due consideration, especially with respect to reaction velocities. Brownian movements in viscous liquids, the application of hydrogen ion concentrations, the elimination of the diffusion potential, etc., are typical examples of the matters that engaged his active and fertile mind. Equally important is his work on the theory of acid-base titrations, the source and elimination of errors in such procedures, ampholytes (dissociation constants of amino acids) and so forth. He was keenly interested in the application of the theory of acidity to soil science, *i.e.*, the discovery of the factors which determine the pH of the soil. The relation between molecular constitution and the first and second dissociation constant of dibasic acids, electrometric measurements with the hydrogen electrode in acid-base mixtures with salts, are still other fields that have engaged his attention.

The work in inorganic chemistry deals primarily with chromium complex compounds. Typically, he approached the numerous problems they presented by physicochemical methods. Colloids, the preparation of collodion membranes with reproducible permeabilities, complex gold salts, and thiocyanogen complexes have also profitted from his able studies.

Professor Bjerrum's "Laerebog i uorganisk Kemi" has gone through five Danish editions and been translated into German, Russian, and English. From 1903 to 1948 he published about 90 papers. In 1939 he was visiting lecturer at Brown University. He holds honorary memberships in the chemical societies of Holland, England, Belgium, Switzerland, and Sweden, and is a member of the academies in Denmark, Sweden, Norway, Vienna, and New York. He is a member of the board of the Carlsberg Foundation, the Rask-Oersted Foundation, and the scientific committee of the Solvay Institute for Chemistry. The Oersted medal was awarded to him in 1928.

[1] See review, J. CHEM. EDUC., **26**, 626 (1949).

SOLUBILITY OF SULFUR: AN UNDERGRADUATE RESEARCH PROJECT

MAXEY BROOKE
Sweeny, Texas

THE director of undergraduate research often finds himself on the twin horns of a dilemma. On one hand, he must assign projects whose theory and technique are not too advanced for the undergraduate student. On the other hand, to be truly research, the projects should yield data that are new and add something to the body of total scientific knowledge. A third difficulty, too frequently, is the lack of funds assigned for undergraduate research.

The determination of the solubility of sulfur in organic solvents meets all these problems. The chemistry student becomes acquainted with the theory of solubility early in his career. The project makes use of only the most elementary laboratory equipment. Not a great deal of work has been done on the subject: Mellor[1] lists only 20 odd organic solvents in which the solubility of sulfur has been determined. And last but quite important, there is little expense involved. Natural brimstone is frequently of sufficient purity for the determinations, but purified sulfur is available at all chemical supply sources and is probably the cheapest reagent listed. Pure solvents are also available at a nominal cost or can be obtained in experimental quantities, without cost, directly from the manufacturers.

For low-boiling-point solvents (below 100°C.), the following technique has been developed. A quantity of solvent sufficient for the tests, say 200 ml., along with more than enough lump sulfur to saturate it (25 to 50 g.) is placed in a flask fitted with a reflux condenser. The flask is put in a steam or water bath and allowed to reflux for some time. Usually overnight is sufficient. The flask is then placed in a constant-temperature bath at a temperature somewhat below the boiling point of the solvent for 5 to 6 hours. A precipitation of sulfur crystals indicates that the solution is saturated at the bath temperature. Since the precipitated sulfur tends to adhere to the sides and bottom of the flask, it is possible to decant small portions, approximately 10 ml., into chilled, tared, weighing bottles. The bottles are quickly stoppered and the solution weighed. The bottles are then opened and placed on the steam or water bath until the solvent is evaporated. The remaining sulfur is then weighed and the solvent determined by difference. Meanwhile, the constant temperature bath is adjusted to a lower temperature, the solution is allowed to come to equilibrium, and the process is repeated until the solubilities of enough temperatures to establish a curve are obtained.

The results can be expressed in a number of ways: mg. sulfur per g. solvent, g. sulfur per 100 ml. solvent (Mellor), or mol per cent S_8.

Liquids in the medium boiling range (100–200°C.) are unsuited to this type of project since their evaporation involves the use of expensive and specialized vacuum equipment.

For high boiling liquids (b. p. above 200°C.) a quite simple technique has been devised. A suitable quantity of solvent (10 g.) and sulfur (10 mg.) is weighed into a 1- × 8-in. test tube. A thermometer and stirring device are inserted into the test tube which is placed in a glycerin or wax bath. The bath material should be transparent, or nearly so, with a good light source behind it. The bath is slowly heated and the mixture stirred until the sulfur has gone into solution. At this point the two-phase system becomes a clear homogeneous solution. The heat is removed from the bath which is allowed to cool at a rate not exceeding 4° per minute. Stirring is continued and the solution observed as the temperature drops until suddenly it becomes cloudy. The temperature at this point is recorded. The change is quite sharp and can be observed and reproduced within 0.2°. This is known as the critical solution temperature, and the ratio of sulfur to solvent can be regarded as the solubility of sulfur at this temperature. The experiment can be repeated with other sulfur-solvent ratios until enough points are available to plot a curve. The system sulfur–dibutyl phthalate has been investigated by the author.[2]

An example of the utility of this project is a series of experiments to demonstrate the influence of chemical structure on solvent power. Etard[3] determined the solubility of sulfur in normal hexane. Hildebrand and Jenks[4] determined the solubility in benzene. Since the structure of cyclohexane is midway between that of normal hexane and benzene, it would be reasonable to assume that the solubility of sulfur in cyclohexane was midway between its solubility in *n*-hexane and benzene.

The sulfur used in the experiment was a sample of very pure natural brimstone having the analysis:

Sulfur	99.983%
Bituminous matter	0.015
Ash	0.002

The cyclohexane was Eastman technical grade.

[1] MELLOR, J. W., "A Comprehensive Treatise on Inorganic and Theoretical Chemistry," Longmans, Green & Co., **1935**, Vol. X.

[2] BROOKE, J. M., *J. Am. Chem. Soc.*, **72**, 5748 (1950).

[3] ETARD, A., *Ann. Chim. Phys.*, [7], **2**, 571 (1894).

[4] HILDEBRAND, J. H., AND C. A. JENKS, *J. Am. Chem. Soc.*, **43**, 2172 (1921).

The experiments were performed as described in the section on low boiling liquids. The results:

Temperature, °C.	*Solubility, grams sulfur/100 g. solution*
11.1	0.716
22.2	1.018
26.1	1.090
44.2	2.016
57.6	2.938
70.6	4.385

The results, when compared with the data of Etard and Hildebrand and Jenks, indicated that the solubility of sulfur in cyclohexane falls approximately midway between the solubility in *n*-hexane and benzene as was predicted.

It would be of interest to carry this study to its conclusion, investigating the effect of chain branching, unsaturation, and substituents.

CURRENT STATUS OF DEPARTMENTAL LIBRARIES IN CHEMISTRY

J. W. BROBERG and R. E. DUNBAR
North Dakota Agricultural College, Fargo, North Dakota

THE North Dakota Agricultural College recently completed a new and modern library building. This brought about a number of important changes in policies and decisions that directly affected and concerned the future status of the departmental library in chemistry. In order to obtain information regarding current practices in similar situations on other campuses a brief questionnaire was prepared and mailed to 166 other colleges and universities of the country. The institutions concerned were those listed as maintaining accredited departments by the Committee on Professional Training of the American Chemical Society.[1] Ninety per cent of the questionnaires were returned, and we believe them to be truly representative of prevailing practices. It was also interesting to note the enthusiastic response, supplementary information, and personal comments that were returned. The questionnaire in each case was mailed directly to the Chairman of the Chemistry Department rather than the institutional librarian and in a high percentage of cases was personally completed by him or by a responsible associate of the department. We intended to obtain chemical facts and opinions only. We believe that the results will be of interest to other departments which have faced similar situations.

A summary of responses to the ten questions follows:

(1) *Do you maintain a separate departmental chemistry library?* The reply indicated that 79 per cent do maintain a separate departmental library apart from the central or institutional library. Of the remaining 21 per cent, 11 per cent have nothing comparable to a departmental library, while the other 10 per cent have a combined library with numerous other sciences such a physics, engineering, pharmacy, etc. It is interesting to note that with only one or two exceptions no major institution is found to be without a departmental library in chemistry.

(2) *Indicate location of departmental chemistry library.* In 72 per cent of the total replies the department library was located in the chemistry building while in 13 per cent of the cases it was located as a separate section in the main library; 15 per cent indicated the location elsewhere. Typical comments referring to items 1 and 2 were as follows: "Have tried both, prefer departmental library," "To be effective the chemistry library should be in the chemistry building," "We consider proximity to research labs. an important factor," "No place satisfactory but in chemistry building," "Departmental library is essential."

(3) *Approximate number of current journal subscriptions received by departmental library.* The number of journal subscriptions varied from two to well over 150 depending largely on the size of the institution. The number of journals so received and percentage of departments receiving them were as follows: 0–20, 21 per cent; 20–40, 32 per cent; 40–60, 12 per cent; 60–80 8 per cent; 80–100, 8 per cent; 100–150, 8 per cent; and over 150, 11 per cent.

(4) *Are duplicate subscriptions of leading chemical journals maintained by your school for use and storage in the main library or elsewhere?* In 24 per cent of the

[1] Progress Report No. 21 of the Committee on Professional Training, *Chem. Eng. News*, **28**, 768–822 (1950).

replies duplicate subscriptions were maintained mostly on a limited number of magazines, principally the *Journal of the American Chemical Society*, and *Chemical Abstracts*. In 62 per cent of the replies, no duplicate subscriptions were maintained, the main reason being lack of funds. In 14 per cent of the cases special arrangements prevailed which could not be satisfactorily classified, involving isolated schools, personal staff subscriptions, and similar situations.

(5) *Are your leading chemical journals bound at regular intervals?* The response indicated this to be the universal practice. Not one exception was noted.

(6) *Approximate number of bound volumes of journals in your departmental library.* The range was 43 to over 20,000 with the size of the school apparently being the determining factor, the largest universities generally having the most extensive collections. The files of the official A. C. S. journals were usually bound and complete, or consistent efforts were being made to secure a complete file. The practice with other journals varied with the importance of the several publications. A further breakdown showed that 11 per cent of the schools had 500 or less bound volumes of such journals, 28 per cent, 501 to 2000, 28 per cent, 2001 to 4000, and 33 per cent, 4000 or more.

(7) *Approximate number of reference books in departmental library.* The situation in relation to reference books followed very closely the trend as indicated in the preceding question. The range was approximately 50 to 12,000. The breakdown indicated 42 per cent of the schools had 1 to 1000 such reference books available in their departmental libraries, 26 per cent, 1001 to 2000, and 32 per cent, 2000 or more. Indications are that most schools have only essential chemistry reference books in their departmental libraries and most other related books are housed in the main or central library.

(8) *Indicate type of departmental library supervision employed.* A full-time paid professional librarian was employed in 35 per cent of the schools reporting. The secretary-librarian combination was found in 33 per cent of the departmental libraries, while 29 per cent used staff members to supervise the library. Only 3 per cent indicated other types of administration, the most common being student help with honor system next in line. In general the full-time professional librarian was used in the largest schools, and the secretary-librarian type in the "middle-sized" institutions, with the other miscellaneous types of supervision employed in general in the smallest departments.

(9) *Indicate regular departmental library hours.* About 60 per cent of the responses indicated that the library was open from 8:00 A.M. to 5:00 P.M., Monday through Friday, and 8:00 A.M. to 12:00 noon on Saturday. Approximately 40 per cent also maintained evening and Saturday afternoon library hours. A few indicated that Sunday afternoon hours were also available. In a few rare instances hours were given as 24 per day and seven days a week.

(10) *Is departmental library available after above hours for use by staff, graduate students, and undergraduates?* In general the response indicated that staff and graduate students have such privileges but they are not granted to undergraduates. In a few instances no one is allowed in the library after scheduled hours.

A number of appended remarks, provided by the individuals who completed the questionnaires, are of unusual significance. A few are included to indicate convictions, practices, and experiences on other campuses.

"These books are located in the main library, a short distance from the present chemistry building, but we feel this arrangement is not satisfactory. We are thoroughly convinced that there should be a library in the chemistry building, available to students in the daytime and to graduate students and faculty both in the daytime and in the evenings."

"I firmly believe that a chemistry department should have its own library in its own building."

"My advice to you would be to hang onto your departmental library if at all possible, and at any cost. This is not possible here, although we have a very good chemical library and a very sympathetic librarian, we wish very much that we had complete control and free access at all times to our library."

"We regard our departmental library, located in our chemistry building, as an indispensable part of an efficient and smoothly working setup for graduate work."

"Our main chemical collection has in the past been in the main library, but is now to be transferred to the chemistry building. I think it would be a great mistake not to have a departmental library."

"Our present quarters do not provide space for the chemistry library. We are anxiously looking forward to the construction of our new building in which we can have practically all of the chemistry books and journals."

SUMMARY

Among numerous conclusions that might be drawn from this study, the following appear to be significant:

(1) Practically all important chemistry departments maintain extensive and well-organized departmental libraries.

(2) The trend is toward the establishment of more and better such departmental libraries.

(3) Most department heads believe that the chemistry departmental library is absolutely essential to the satisfactory development of an efficient and up-to-date department.

(4) Good administration and supervision of a departmental library is essential.

(5) A departmental library should be available to all students under conditions comparable to those of the main library.

(6) The advantages, among others, of a well-organized chemistry departmental library, are greater convenience, a saving of time, greater increase in the use of journals and reference books, and a definite aid in the production of research workers and chemists.

TITERS

PHILIP W. WEST
Louisiana State University, Baton Rouge, Louisiana

THE present discussion is intended to emphasize the need for teaching the methods of calculation which apply to quantitative analysis and to show how such calculations can be taught, or self-taught, by logical development of thought. The pedagogical and practical advantages of the use of the titer method will be stressed in the discussion of calculations pertaining to titrimetric analysis.

The most obvious reason for teaching analytical chemical calculations is the practical need for students to know how to evaluate laboratory data. While many textbooks and even research papers include formulas for calculating percentages from simple data obtained by chemical manipulation and physical measurement, there is no real justification for such formulation: any one who has had formal training in the laboratory work should also know the principles on which the laboratory methods are based, which in turn implies the ability to apply mathematics to the various phases of the analytical procedure.

A second reason for stressing calculations, a reason seldom considered, is that working a variety of problems enhances the students' perspective concerning actual procedures used in the broad scope of quantitative work. In formal laboratory instruction few undergraduate students come in contact with more than a dozen or two dozen determinations—this is indeed a small percentage of the many hundreds of accepted procedures applied in classical quantitative analyses. Yet by proper stress of chemical stoichiometry the over-all simplicity of quantitative analysis can be impressed on students, and they can be given a broad perspective of the common approaches to a wide variety of practical analytical problems.

A third reason for emphasizing calculations in the quantitative analysis course is the need to instill in the student a feeling of confidence. The acquired ability to put chemistry on an exact, mathematical basis is generally the climactic point in the development of the chemistry students.

The preceding paragraphs have implied a scope generally limited to stoichiometric calculations. Certainly in the elementary quantitative analysis course this is reasonable although equilibrium calculations should be introduced or reviewed. The extent to which the Law of Mass Action is considered must depend on the nature and the success of previous instruction as well as the time available for such work in the quantitative course. Certain special phases of analytical calculations should be considered, the extent depending upon the time available. The importance of significant figures and the use of statistical methods must be introduced. Calculations applying to special methods of analysis may be introduced, if time is available, as in the case or volumetric (gas) and colorimetric methods. Potentiometric and other electrometric methods should be considered, although calculations in such cases can be presented as integral parts of the theory; if such methods are not studied in the elementary course detailed consideration can be deferred until the course in physical chemistry or instrumental analysis is taken.

LOGICAL DEVELOPMENT OF STOICHIOMETRIC CALCULATIONS

Much of the success of teaching chemical calculations depends on logical development of concepts and methods.[1] Referring a student to isolated problem types may serve some purpose but usually adds little to his understanding unless he is a superior student with exceptional ability to deduce and correlate.

The following approach is readily understood by most students and seems to the author to be the most logical presentation. Titers are used in the introduction of titrimetry, although the normality system can be developed for later use. More detailed consideration of titers and normalities will be given later in this discussion.

Atomic and Molecular Weights. No special concepts exist that need to be brought out—this is one of the few places where it seems safe to assume prior knowledge.

Equivalent Weight. The fundamental principles of equivalency are known to most of the students although a working knowledge of equivalency is often lacking, especially in the case of redox systems. Equivalent weights of redox agents should be presented as a special topic with considerable emphasis after the discussion of neutralization and precipitation procedures in titrimetry; they do not enter into problems encountered in gravimetry.

A useful rule for ascertaining gram equivalent weights in the case of double decomposition reactions is given by the expression

$$\text{Gram equiv. wt.} = \frac{\text{Mol. wt.}}{\text{Total valence of either the cation or anion involved in the reaction}}$$

The idea of total valence and the words "involved in the reaction" are to be stressed.

Chemical Factor. The chemical (or conversion) factor, which is used to convert a given weight of one pure substance to the corresponding or equivalent weight of

[1] WEST, P. W., "Calculations of Quantitative Analysis," Macmillan Co., Inc., New York, 1948.

some other pure substance, is readily understandable to the average student when presented on the basis of equivalent weight ratios of the substance sought to the substance given. A good rule that can be suggested is to set up chemical factors so that common atoms (other than oxygen) appear the same number of times in the numerator as in the denominator—*e. g.*, to convert Fe_2O_3 to Fe_3O_4 the correct factor is $2Fe_3O_4/3Fe_2O_3$. Such a rule obviously is based on the assumption that any commom atom, other than oxygen, is the subject of study and must be maintained in equal numbers throughout all operations. Although there are a few exceptions, this is a good working guide which is generally helpful and may actually be indispensable where mixed valence states are encountered.

Gravimetric Analysis. The concepts of gravimetry are essentially those just developed. Students readily understand that gravimetric analyses are based on the isolation of the desired substance in pure form, and that once a pure representative compound is obtained corresponding weights of the element, ion, or molecule in question can be computed by means of appropriate chemical factors.

Titrimetric Analysis. In quantitative analysis the ultimate objective is almost without exception to find the *weight* of some desired substance. Knowing the weight of substance, final results can be expressed in terms such as percentage, parts per million, or weight per unit sample. For example,

$$\text{Percentage of } A = \frac{\textit{Weight of } A \text{ found} \times 100}{\text{Weight of sample}}$$

The preceding remarks are to be stressed so as to introduce the fundamental merit of the titer method of calculation.

A *titer* is the *weight* of pure substance corresponding to 1 ml. of solution. In titrimetric analysis, therefore, the weight of substance found by titration is obtained by simple multiplication of the appropriate titer by the number of milliliters of titrant used. Not only is this the most direct and simple method of calculation but it must be the most easily understood by the student. In the case of a soda ash analysis, for example, the weight of Na_2CO_3 found by titration would be the sodium carbonate titer of the titrant, say hydrochloric acid, multiplied by the volume (ml.) of titrant used.

$$\text{Weight } Na_2CO_3 \text{ found} = Na_2CO_3\ T_{HCl} \times V_{HCl}$$

It is often overlooked that standard solutions are obtained only by ascertaining a weight-volume relationship (hence, titer). In the case of silver nitrate, standard solutions may be obtained by diluting a known weight of the pure salt to a known volume ($AgNO_3$ T_{AgNO_3}), precipitating pure silver chloride from a known volume of the solution (AgCl T_{AgNO_3}), or by titrating a primary standard such as pure sodium chloride (NaCl T_{AgNO_3}).

From the viewpoint of pedagogy it is easily pointed out that knowing any titer enables one to calculate any other desired titer by means of chemical factors because titers are *weights* of pure substances represented by each milliliter of solution. To those who have thought that normality methods are essential in establishing the concepts of equivalency it can be remarked here that any calculation comparing the weight of one pure substance with that of another teaches the principle of equivalency—placing the matter on a basis of equivalents per liter certainly adds little or nothing to the appreciation of this concept.

Redox Calculations. Practically all redox methods are based on titrimetric procedures and as such involve titers (or normalities) as discussed above. The fundamental distinction between redox calculations and double decomposition computations lies in the different criteria used for determining equivalency. In the case of oxidation or reduction reactions equivalence is established on the basis of the number of electrons lost or gained. An aid in teaching redox equivalents, where students question the multiplicity of possibilities, is to point out that only selected valence changes are of interest (*e. g.*, Fe^{++} to Fe^{+++}); regardless of initial oxidation states the element to be determined is adjusted to the proper initial form and the titration performed measuring the standardized reaction. A good analogy is a speed run, say at Muroc Lake, where a plane may be shipped or flown in—the record trial is then run over the specified course with no interest being paid either to the approach speed or the return flight.

TITERS AND NORMALITIES

Both titer and normality methods of calculating the results of titrimetric analysis are well established and should be familiar to all analytical chemists. Two important advantages favor the titer method: first, titers are more direct—to the extent of one or two mathematical operations—and so find greatest favor in industrial laboratories where time and accuracy are of prime importance; second, titers are more logical and so are easier to teach.

The main advantage of normality (or milliequivalent) methods is their general acceptance. For many years such methods have been taught almost exclusively and so normality is the common basis for titrimetric designations and calculations (European chemists, however, seem to favor titers). Unless one can speak in terms of normalities and milliequivalents, therefore, one is seriously handicapped at present. An interesting observation at this point is that titer methods are increasing in popularity in spite of the fact that few teachers give proper emphasis to their applications.

From the standpoint of pedagogy, it is recommended that titers be taught in the introduction of titrimetric methods. Once titrimetry is established for the student he can be instructed in the use of normalities and milliequivalents without confusion. The relationship between titer and normality is shown by the expression

$$\text{Normality} = \frac{\text{Titer} \times 1000}{\text{Gram equiv. wt. of substance in terms of which the titer is expressed}}$$

CONCLUSION

The calculations of quantitative chemical analysis can be taught most easily by logical development of thought. Because titers are the weights of pure substance corresponding to a milliliter of titrant they fit into the logical approach to stoichiometric calculations, the sequence of study being: atomic weights, molecular weights, equivalent weights, chemical factors, gravimetric analysis, titrimetric analysis. In titrimetry, titer × volume = weight found. A known titer multiplied by appropriate chemical factors gives any desired additional titers—the whole thought process involving weights without the abstraction of normalities.

In support of the use of titers the following points are cited in the belief that their use in teaching stoichiometric calculations should become more widespread.

(1) Titers are becoming the most widely used in industrial laboratories; therefore students should be taught methods they will encounter upon graduation. In this regard it might be mentioned that since normality methods have been most generally taught, many graduates can only use titers on an empirical basis—when solutions of specified normality are available. Also, many people use titers without realizing it by labeling standard solutions with "factor," "values," or "equivalents," or by such designations as "1 ml. = 0.005 g. Fe."

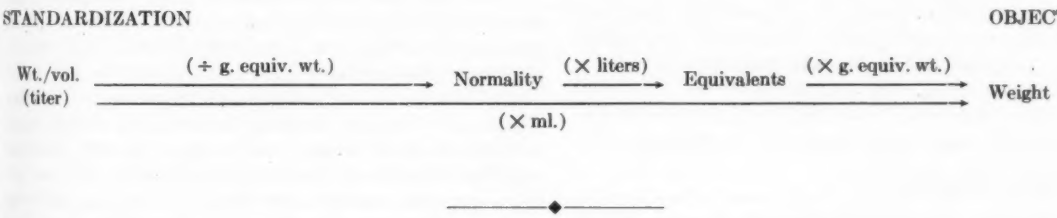
(2) Titer calculations are the simplest to use. The weight of substance found is obtained by simple multiplication of the titer by the volume (titer × ml. = weight), while in the case of normality methods, volume times normality gives equivalents which must then be converted to weight through multiplication by the appropriate gram equivalent weight (normality × liters × gram equivalent weight = weight).

(3) Titer calculations do not suffer from ambiquity as does the normality system.

(4) Titers are the most accurate. Two basic reasons can be cited for this statement: first, titer calculations involve either one or two operations less than normality methods, depending on whether or not normalities have been previously calculated from the standardization data, and it is obvious that each mathematical step eliminated reduces chance of error; second, lack of ambiguity in the case of titers eliminates one of the important sources of error.

(5) Titers most closely resemble engineering methods. Production calculations are based on weight per unit volume (*e. g.*, pounds/gallon), and it would be a rare case if an engineer were to think in terms of adding 750 gallons of 5 *N* caustic to a reaction vessel.

(6) Titers are most easily understood and consequently are the easiest to teach. The more direct a concept, the more readily it can be assimilated.



IT'S YOUR DIVISION

DIVISION OF CHEMICAL EDUCATION
of the American Chemical Society

NEW officers of the Division will be elected at the New York meeting where the Nominating Committee will present the following candidates:

Chairman-elect—Paul H. Fall, Hiram College, Hiram, Ohio.
Secretary—Calvin A. Vander Werf, University of Kansas, Lawrence, Kansas.
Member-at-large—William S. Kieffer, Wooster College, Wooster, Ohio.

Additional nominations may be made from the floor.

As has been pointed out recently in these pages, a proposal for election of officers by mail ballot will also be presented at that time. The business meeting will probably be held Thursday afternoon at the close of the scheduled symposium (see final printed program to be sure) and it is hoped that every member of the Division who is in New York will be able to attend the meeting.

I should like to take this opportunity also to welcome Hubert N. Alyea of Princeton as the new Chairman of the Division and to thank all the officers and members with whom I have worked for their suggestions and support toward the improvement of the Division. Particular mention should be made of the ten years of service of Paul H. Fall as Divisional Secretary.

J. A. CAMPBELL

Proceedings of the

PACIFIC SOUTHWEST ASSOCIATION OF CHEMISTRY TEACHERS

TEACHING ANALYTICAL CHEMISTRY[1]

LOUIS LYKKEN
Shell Development Company, Emeryville, California

IT IS generally agreed that analytical chemistry courses are an important feature of college curricula for the training of chemists and chemical engineers. However, there is not complete agreement in the role and scope of such courses because of the unpredictable placement of chemically trained college graduates. This dilemma poses a problem but it appears resolvable by compromising the needs of graduate work, industry, and teaching, the three important fields which absorb the chemically trained graduate. Actually, these three fields need about the same emphasis on basic analytical training and there is little conflict in the desired analytical coursework except in the special case where the student is being prepared for industrial analysis. Since the latter case requires only augmentation of the basic groundwork, this paper deals only with the teaching of undergraduate analytical chemistry in general.

FIRST-YEAR COURSE

The first-year preparatory chemistry course should consist of the conventional study of general chemistry with at least one-third of the year devoted to qualitative inorganic analysis and with about equal emphasis on class and laboratory work, especially in the qualitative portion. If possible, it is desirable to include some organic chemistry, stressing empirical formulas and prominent reactions. In order to promote understanding and reasoning the emphasis should be on the basic chemical background and practical problems, including simple analytical calculations, and not on specific details and properties. Putting it another way, the instruction should stress qualitative separation of like elements into groups and emphasize the chemistry of the group. A suitable way of accomplishing this is to note similarities and differences between common elements and typical compounds, and to study type reactions rather than commercial processes and materials. Some thread of reasoning should be supplied which the student can use for connecting the chemical facts learned.

SEQUENCE OF COURSES

After the first-year chemistry course, the sequence of the basic courses in chemistry and physics is an important consideration. It is desirable to coordinate the analytical chemistry course with these related courses in order to allow a logical progression of learning, to avoid repetition of theoretical expositions, and to give an opportunity for stressing various aspects of analytical chemistry. These considerations suggest the following sequence of important chemistry courses: (1) give the conventional quantitative (inorganic) instruction in the second year along with advanced qualitative analysis and/or organic chemistry; (2) teach physical chemistry and organic chemistry in the third year if the latter has not been given before; (3) offer a full year course of technical analysis in which rigid or elaborate proof of laws and concepts should be minimized and the stress should be on variety of work rather than specialization in a few fields. It is desirable to place equal emphasis on class and laboratory work and to give one-third of a year each to qualitative organic and quantitative analysis and to modern concepts and tools of analysis. The basis of electrometric, spectrophotometric, and other physical analytical techniques should be taught in the physical chemistry or physics courses.

A full-year course in physics is an important adjunct to the second-year chemistry courses because progress in modern analytical chemistry involves measurement of physical properties of various kinds and because physics is the basis for the instrumentation of methods. If a choice is necessary, physics is considered of greater value than advanced courses in chemistry, excepting organic chemistry. Training in physics is of considerable value in a general way because it stresses the practical use of mathematics.

QUANTITATIVE ANALYSIS

Laboratory Work. Normally, there should be two three-hour laboratory periods per week devoted to quantitative analysis throughout the second year, but consideration should be given to providing three such periods in the last third of the work. While optional to

[1] Based on a paper given at the meeting of the Northern California Section of the Association on October 21, 1950, at Mills College.

some extent, the elementary gravimetric work should come first, starting with very simple determinations designed to give the student confidence in his work. The volumetric work should be given in the middle of the year but only the initial standard solutions should be standardized by the student. Standardized solutions should be provided where the emphasis is on separations, end points, etc. In general, the samples should be homogeneous, easily soluble, and known to the instructor; 8 to 12 samples should be used for gravimetric practice and 10 to 15 for volumetric tests. At least one sample should involve several separations (*i. e.*, limestone or brass) and, where possible, samples of commercial materials should be utilized. Weights and a buret should be calibrated sometime during the year. All common quantitative techniques should be covered and the last three or four determinations should involve a difficult separation, titration, or analytical step. Time should not be wasted in building crude apparatus; instead standard commercial units should be provided. After the first third of the work, rapid balances should be available for regular use.

The teaching practice used in the laboratory is important and requires intelligent study. It is necessary to demonstrate critical points individually at the right time. A few experienced instructors are generally more effective than a number of inexperienced ones because the former can detect the opportune time for the demonstration and know what difficulties are to be anticipated. All class instructors should spend some time in the laboratory and individual demonstrations should be used when possible. Proper format for the record book should be taught and stress should be put on the student's ability to translate results properly in making a report. Safety needs should be stressed and emphasized when a possible hazard is encountered. To this end, safety apparatus should be readily available and the students required to use it.

Classwork. While more time can be used profitably, a suitable compromise is to spend two one-hour classes per week teaching analytical chemical theory, problems, and basic background of the apparatus used in the laboratory work. An important feature of the classwork is to present and explain the unit operations of analytical practice (*i. e.*, filtering, weighing, titrating, calibration, etc.) and to teach the basis for the laboratory experiments. An important responsibility of the instructor is to develop in the student an ability to schematize the knowledge received and to develop his willingness to learn in a serious manner. It is the function of the instructor to inspire his students to learn "why" through thought and interest, thereby achieving a real understanding of the subject by thinking "analytically." It is desirable to use ample time to present important features, to cover the subject well, and to avoid teaching too much too fast. The basic physical and chemical principles should be taught thoroughly and the student should be trained to state them fully yet concisely. A good way to develop this talent is to give tests regularly, requiring statement-type answers. It is also desirable to give "open-book" final examinations because they are a good test of the students ability to think; in such examinations, it is important to provide a varity of questions or problems and to give ample time for their solution.

The classwork should be a combination of lectures, quiz-sessions, and problem-teaching. All possible presentations and considerations should be related to practical usage and, obviously, the instructor should be familiar with illustrative practical applications. The significance of the various chemical and physical laws should be stressed but their derivation and justification can be left to other basic courses in the curriculum. Considerable emphasis should be placed on precision, accuracy, and significance of analytical figures.

Problems are an important feature of analytical chemistry because they aid in developing analytical thinking and serve to broaden the field of interest. It is important to select a sequence of problems that requires an increasing degree of deductive and inductive reasoning. As in laboratory work, it is desirable to start with very simple problems in order to develop the student's confidence in solving them. In addition, it is necessary to repeat certain types to emphasize the reasoning used. It is generally preferable to select problems that are based on actual analytical processes and that have answers that fall in a practical range. Thus, problems can be used to teach the student a proper sense of analytical values and to develop thinking along analytical lines.

TECHNICAL ANALYSIS

The purpose of the final course in analysis should be to encourage interest in analytical chemistry and to teach an understanding of its possibilities as a service. Such a course should be equally useful to a person eventually doing chemical analysis or using data obtained in analysis. This course should be given in the senior year so that basic principles already learned can be utilized with a minimum of effort; it should include both qualitative and quantitative applications and should consist of two one-hour classes and two three-hour laboratory periods per week.

It is advisable to separate the work in three parts. One-third of a year can be profitably devoted to organic analysis, dividing the coverage between qualitative identification of compounds and quantitative determination of functional groups. Another third of a year can be used for a study of general fields of technical analysis, comprising gas analysis, fuel analysis, microanalysis, metal analysis, etc. It is desirable to select the laboratory work and class work to illustrate (1) new reactions, (2) complexing reagents for performing separations, (3) utility of columns (distillation and chromatographic) as separation tools, (4) sampling techniques, (5) means of sample decomposition, etc. The last third of the year should involve the use of modern instruments for analysis, such as pH meters, titrometers, polarographs, electrolytic apparatus, spec-

trophotometers, simple colorimeters, emission spectrographs, etc.

The presentation and arrangement of the necessary class and laboratory work need careful study and planning. A general treatment is best in order to cover the most ground. The instructor needs to instill in the student an appreciation for new approaches and a familiarity with them. There is little value in intensive study of a narrow field because of the uncertain use of such specialization. It is important for the student to have contact with actual commercial apparatus and practical samples. There is little to be gained from wasting the student's time on building apparatus except the simplest kind. Where apparatus is not readily accessible, it is desirable to discuss the utility of such equipment from photographs and drawings and to visit laboratories where such apparatus can be inspected and demonstrated. Another important feature of the classwork is to teach the proper use of analytical literature and reference books. Thus, the student should be required to look up some of the information needed for class or laboratory work.

RESEARCH PROJECTS

Whenever it can be worked into the curriculum, all students in chemistry or chemical engineering should do a research project in the senior year. Such a project should require at least half of a year and should culminate with the writing of a report or a thesis. This work should teach the proper approach and handling of practical problems of restricted scope, and should not be connected with the regular line of graduate research work being done. The project should require the writing of one or more progress reports.

THE EFFECT OF NITROUS ACID ON THE OXIDIZING POWER OF NITRIC ACID

A Lecture Demonstration

ROBERT C. BRASTED
University of Minnesota, Minneapolis, Minnesota

To most students in general chemistry nitric acid typifies *the* oxidizing agent. The following lecture experiments will dispel this idea and demonstrate, as Feigl[1] has shown, that the oxidizing action of nitric acid may be considerably enhanced by small quantities of nitrous acid which are usually present.

PROCEDURE

Decolorizing HNO_3. Place portions of concentrated HNO_3 in each of two beakers (beakers 1 and 2). Point out that the yellowish color is due to traces of NO_2 in the acid, which also contains NO and HNO_2. Some reactions are

$$4HNO_3 \xrightarrow{\text{heat, sunlight}} 2H_2O + O_2 + 4NO_2$$

$$2NO_2 + H_2O \xrightarrow{\text{cold}} HNO_3 + HNO_2$$

$$3NO_2 + H_2O \xrightarrow{\text{hot}} 2HNO_3 + NO$$

$$2HNO_2 \longrightarrow H_2O + NO_2 + NO$$

Add about 0.5 g. of sulfate-free sulfamic acid to the acid in beaker 2; in half a minute the HNO_3 becomes colorless as the nitrous acid is removed[2] by the reaction

$$HNO_2 + HSO_3NH_2 \longrightarrow N_2 + H_2SO_4 + H_2O$$

Effect of HNO_2 on dilute iodides. Stirring constantly, run in a few ml. of the yellowish acid from beaker 1 into a starch-iodide solution in beaker 3. Immediately run an equal volume of the colorless liquid from beaker 2 into a similar starch-iodide solution in beaker 4. The instantaneous appearance of starch-iodine blue in beaker 3, in contrast to its slow formation in beaker 4, shows the catalytic effect of the HNO_2 which was in beaker 1. This idea is substantiated by adding a crystal of $NaNO_2$ to the mixture in beaker 4, resulting in immediate blue coloration.

Oxidation with concentrated HNO_3. Finally, drop crystals of KI into beakers 1 and 2. Vigorous reaction in both cases, with liberation of iodine, demonstrates that concentrated acid, even in the absence of HNO_2 in beaker 2, will oxidize the iodide ion to free iodine.

[1] Feigl, F. *Anais assoc. quim. Brasil*, **1**, 234 (1942); J. Chem. Educ., **20**, 139 (1943); **21**, 347 (1944).

[2] Other methods of decolorizing the HNO_3 are: (*a*) Boil the acid and cool; this is slower than the sulfamic acid method. (*b*) Add urea—but the urea also interacts with the HNO_3. Sulfamic acid will not interact with the HNO_3 unless it is hot or its concentration is above 73 per cent. (*c*) Add sodium azide; but take care, since the azides are poisonous and certain of them are explosive.

Report of the

NEW ENGLAND ASSOCIATION OF CHEMISTRY TEACHERS

OFFICIAL BUSINESS

261ST MEETING

The meeting was held at Walnut Hill Schoop, Natick, Massachusetts, May 12, 1951. President Helen W. Crawley opened it by presenting Hester R. Davies, Headmistress of the school. Miss Davies, in welcoming the NEACT to the campus, congratulated the members for their greater success in influencing history in the past 50 years than the history teachers, with whom she identifies herself, have been able to do. She remarked that the successful impact of science teaching during the past 50 years requires no elaboration, but the beneficial effects of teaching history and man's ability to learn lessons from history are less readily discerned. The meeting was then turned over to the Chairman of the Central Division, Ina M. Granara of Simmons College, who introduced the speakers.

Dr. Arno Heyn, of Boston University, who discussed "Teaching analytical chemistry in the age of instrumentation," discussed the content of the introductory courses in chemical analysis from several standpoints: (1) What are the end uses of the course? (2) How much instrumentation should be introduced in the introductory courses? (3) If new material is put in, what may best be left out? (4) How much laboratory work is required? He concluded that because of the increased need for factual and theoretical background, the elementary courses in analysis should not be turned into courses in instrumentation. This should come later. To conserve time, instruction techniques can be improved; visual aids such as motion pictures and 35-mm. Kodachrome slides may be used to present factual information with a great saving in time. Slides prepared for lecture demonstrations were exhibited.

The next speaker, Mrs. Diana Ballin Abbott, of Simmons College, spoke on "Nutritional high lights—1951." Her fascinating review of recent discoveries in the field of human nutrition stimulated much discussion. Her talk was followed by one by Dr. Jean Caul of Arthur D. Little, Inc., on "Chemical sensing" which emphasized the importance of the superficial aspects of foods—appearance, taste, smell, and feel—for acceptability by the individual. The contrast between the slow, laborious growth in insight into human nutrition resulting from scientific study and the frequent perversion of principles of good nutrition to glamorize the superficial aspects of food (sales appeal) exhibited by the commercial purveyors of food did not escape the listeners.

Luncheon was provided, after which the divisional business meeting and the annual meeting were held. After the closing of these business sessions, Dr. Arthur E. Martell of Clark University spoke on "Recent development in metal chelating agents and their use." He illustrated his talk by experiments involving sequestration of ions by means of ethylene diamine tetraacetic acid (Versene). Besides softening of hard water, he showed how the concentrations of metal ions in aqueous solutions could be determined by acid-base titrations involving use of this reagent. Mention was made also of use of sequestering reagents for "decontamination," that is, removing radioactive isotopes and fission products from contaminated equipment.

REGULAR BUSINESS MEETING

The co-chairmen of the Summer Conference Committee, Donald C. Gregg and William S. Huber, reported on the state of advancement of their plans. Efforts are being made this year to assemble a greater number of exhibits than formerly, under the chairmanship of George Deckey of the Rhode Island School of Design. The plans for the clambake have been reviewed with the decision that an elaborate, standard Rhode Island clambake will not be feasible; a picnic with some sea food items included will be planned instead.

The Membership Committee announced the election to membership of Professor Walter Richie of the University of Massachusetts, Amherst, Massachusetts.

ANNUAL MEETING

The following report, submitted by the Secretary, Dorothy W. Gifford, was read by President Helen Crawley.

Report of the Secretary. Attended by 191 registrants, the Twelfth Summer Conference provided the usual opportunities for friendly interchange of ideas, renewed inspiration, and increased information. To many of the members of the NEACT the conference each year becomes increasingly a "must" in the summer's program.

As usual, five meetings have been held during the scholastic year:

October 14, 1950, at Nashua High School, Nashua, New Hampshire
December 2, 1950, at Simmons College, Boston, Massachusetts
February 10, 1951, at St. George's School, Newport, Rhode Island
March 24, 1951, at Pomfret School, Pomfret, Connecticut
May 12, 1951, at Walnut Hill School, Natick, Massachusetts

Average attendance of the first four was 82. The Simmons

meeting is probably the first at which a host institution actually began to have doubts about being able to accommodate the size of the group attending. There were well over 200 at this meeting.

The Executive Committee has dealt with the problems of the selection of dates and places for the meetings, the budget, the appointment of a chairman for the 13th Summer Conference, and general matters of Association policy.

After considerable discussion, it was voted to set up a classification of deferred membership such as was used during the last war for members in the military services. They will receive notices of the meetings and copies of the *News Letter*, but will not receive the JOURNAL OF CHEMICAL EDUCATION unless they retain their active membership status. It was further voted that at the discretion of the Executive Committee other members may be considered as belonging in this category, such as E. Harold Coburn, on a year's leave of absence in India, and Mary C. Rogers, exchange teacher to England.

The Curator, Ralph E. Keirstead, has been authorized to draw up some suitable form of certificate to be presented to honorary members.

The Executive Committee wishes to express again this year its debt of gratitude to the Rev. Leo J. Daily who has so kindly acted as publicity agent and has been instrumental in obtaining good newspaper publicity for each of our meetings.

We are glad to announce that Laurence S. Foster has consented to act as editor of the *Report* and of the *News Letter* for the coming year. We may well be proud of our official section in the JOURNAL, and the comments in regard to the *News Letter* have been enthusiastic and grateful.

It is the very real desire of the Executive Committee that the affairs of this Association shall be conducted in accordance with the wishes of its members, and it welcomes suggestions in regard to Association policy. Since we wish any action which we take to reflect the opinion of the membership in general, criticism will be welcomed.

I cannot relinquish my post as secretary of this Association without exercising that supposedly feminine prerogative of having the "last word." I should like to say that, even though the job is one which is time-consuming and requires, at times, considerable patience, it is also one which is richly rewarding. The past six years have brought a wealth of friendships and contacts for which I shall always be grateful. I have had the privilege of working with a group of people who indulge heartily in generous cooperation and contagious enthusiasm, people who are singularly free from the pessimism and fatalism for which there can be no room in the teaching profession.

The secretary's report was received with applause and it was voted that the President be instructed to write a letter to Dorothy W. Gifford, who has served so ably as secretary for the past six years, expressing the appreciation of the Association for her outstanding services.

Dorothy W. Gifford, Chairman of the Membership Committee, submitted the following report.

Report of the Membership Committee.

Active members at the close of the fiscal year 1950		519
New active members, 1950–51		50
		569
Resignations	18	
Dropped for nonpayment of dues	35	
		53
Total active members		516
Deferred members		3
Total Members, March, 1951		519

The lack of increase is due in part to the rather unusually large number of resignations occasioned by retirement, by changing from teaching to industry, by matrimony, and by removal to distant places. In no cases has there been any complaint about the service of the Association to its members, and almost without exception expressions of friendly gratitude and appreciation have accompanied the letters of resignation.

The members who have been dropped for the nonpayment of dues must represent, for the most part, members who have not received from the Association what they feel that they have a right to expect in the way of inspiration and help. The increased cost of living makes membership in associations like ours one of the first things to be dropped in an economy move unless the program which we offer plays a vital part in a person's academic career. The responsibility for making the NEACT of real value to teaching in general rests with each individual member. We can continue to grow only if members will suggest possible candidates for membership, will urge others to join, and will participate with vigor and enthusiasm in the general activities of the group.

The Treasurer of the Trustees Permanent Trust Fund, Avery A. Ashdown, submitted the following report.

Report of the Endowment Fund Committee.

Balance, May 4, 1950		$2116.96
Income credited in the period May 4, 1950 through May 7, 1951		
Watertown Cooperative Bank	$22.52	
Newton Savings Bank	22.80	
Two per cent of dues, 1949–50	35.85	81.17
		$2198.13
Investments, May 7, 1951		
Five matured shares Watertown Cooperative Bank at cost		$ 994.91
Balance in the Newton Savings Bank		1203.22
		$2198.13
Income for the year, May 4, 1940, through May 7, 1951		$ 81.17

The following report was submitted by the Curator, Ralph E. Keirstead.

Report of the Curator. By and large, the duties of the curator are rather routine—keeping up to date the permanent membership file (incidentally 1791 members have been admitted to membership since the founding of the Association), sending a packet of materials about NEACT to new members, and maintaining the file of data concerning the activities of the Association and its members.

One new duty has been assigned to the curator during the past year. A card file of all secondary schools in New England with an enrollment of over 75 pupils has been organized. If a school has an Association member on its staff his name appears on the card for that school. This file gives complete data on the distribution of our members in secondary schools—public, private, and parochial. Prior to the December, February, March, and May meetings, the curator sent to the proper division chairmen approximately 100 stamped envelopes addressed to the Instructor of Chemistry of schools in which there are no NEACT members. The Division Chairmen have enclosed a program of the meeting and other promotional material. This is a regular procedure for bringing the association to the attention of nonmember chemistry teachers. Coupled with personal solicitation by members, it should add strength to our continuing membership campaign.

During the year, all questionnaires received from members have been placed in looseleaf notebook covers and a notation to that effect has been made on the permanent membership card.

Mary B. Ford, Amasa F. Williston, and Ralph E. Keirstead made the report which follows.

Report of the Committee on Honorary Membership. The Executive Committee has accepted the report of the Honorary Membership Committee and recommends the election of two persons to honorary membership at this meeting.

SAMUEL T. ARNOLD of Brown University has maintained membership and active interest in this association for 30 years while serving his university as a distinguished teacher, as Chairman of its Department of Chemistry, as Dean, and now as Provost. As assistant to General Leslie Groves, Professor Arnold rendered great service to the nation in recruiting scientific personnel from the universities for work on the Manhattan project.

ELDIN V. LYNN of the Massachusetts College of Pharmacy has been a member of this association since 1937. Few persons in a space of 14 years have given more time and energy to serving this organization. Professor Lynn has been a regular attendant at meetings, an able officer, and a one-man membership committee in no small measure responsible for the present large membership.

The two nominees were elected to honorary membership.

The following officers were elected for the next year:

President—Helen W. Crawley
Vice-President—Dorothy W. Gifford
Secretary—Leallyn B. Clapp
Treasurer—Carroll B. Gustafson
Curator—Ralph E. Keirstead
Auditor—S. Walter Hoyt
Northern Division Chairman—Marco H. Scheer
Central Division Chairman—Ina M. Granara
Western Division Chairman—Carl P. Swinnerton
Southern Division Chairman—Leslie B. Coombs
Trustee of the Endowment Fund (3 years)—Avery A. Ashdown
Member of the Nominating Committee (3 years)—Amasa F. Williston

Recent Books

BRIEF COLLEGE CHEMISTRY

Leon B. Richardson, Emeritus Professor of Chemistry, and *Andrew J. Scarlett,* Professor of Chemisty, Dartmouth College. Revised edition. Henry Holt and Co., New York, 1951. ix + 470 pp. 56 photos. 104 figs. 58 tables. 16 × 24 cm.

LABORATORY MANUAL FOR BRIEF COLLEGE CHEMISTRY

Richardson and *Scarlett.* Revised edition. Henry Holt and Co., New York, 1951. viii + 229 pp. 18 figs. 21 × 28 cm.

THIS is a thoroughly revised edition of a text that has been well received since 1942. "This book is designed for introductory college courses in general chemistry where there is a restrictive limitation in the time assigned to the work." Anyone who is teaching such a course should seriously consider this text. The textual material is neither highly elementary nor so extensive that a large proportion of the book must be omitted or hurried over superficially in a course of less than six semester hours' lecture credit. Despite its limited length the book's 35 chapters cover the essential principles and the conventional subjects of general chemistry in a very efficient manner. Each chapter ends with a list of thought-provoking exercises. Where they are pertinent, adequate problems are given. The text is well balanced as regards the relative amounts of space given to different types of subject matter. The explanations of chemical theory are modern and clearly stated. The industrial processes are usually quite up to date.

Atomic structure and the periodic classification of the elements are introduced early in the course. A full chapter, Chapter 5, is devoted to nuclear fission. The types of valence are clearly discussed and are explained on the basis of atomic structure. The Brønsted terminology is used for a thorough discussion of acids, bases, and ionic reactions. Both ionic and molecular equations are used liberally throughout the text. Emphasis is placed on the balancing of equations, including oxidation-reduction reactions.

The text does not include historical material. There are no references to guide the student to further reading. Only three chapters are devoted to carbon and its compounds; hence the book is not adequate for a course that attempts to cover the whole field of chemistry in a single course.

The book is attractively printed and bound. The pictures are modern and the line drawings are clear and informative.

The laboratory manual was written to accompany the text. The proposed exercises are quite simple and would not require much time to perform. The instructor is expected to provide most of the directions for laboratory techniques. Each section of directions for experimentation is followed by a report section in which the student is expected to record his observations and to answer the questions. The manual is wire-bound. The report sheets may be torn out if desired.

JOHN B. ENTRIKIN

CENTENARY COLLEGE
SHREVEPORT, LOUISIANA

NUTRITION AND CHEMICAL GROWTH IN CHILDHOOD. VOLUME III

Icie G. Macy, Research Laboratory, Children's Fund of Michigan. Charles C Thomas, Springfield, Ill., 1951. xliv–lx + 1461–2174 pp. 842 tables. 16 × 24 cm. $8.

USERS of the first two volumes of this work will find the third volume of considerable interest. It contains the calculated data for 41 individual children during some 1000 balance periods representing all together more than 6000 experimental days. Tables give average daily values for intake, absorption, and retention of nutrients referred to kilograms of body weight, centimeters of recumbent body length, and square meters of body surface. A section is devoted to each of the following: Nitrogen, protein, carbohydrate, fat, heat of combustion, energy expenditure, physiologic fuel value, phosphorus, chlorine, sulfur, calcium, magnesium, potassium, sodium, and excess of positive or negative minerals.

A supplement by J. O. Holmes includes tabulated means of data collected under her direction and presented in Volume II.

An appendix contains interpretations and tabulated data of roetgenograms of 17 children intended to make possible an assessment of skeletal maturation.

PHILIP H. MITCHELL

BROWN UNIVERSITY
PROVIDENCE, RHODE ISLAND

ADVANCES IN CARBOHYDRATE CHEMISTRY VOLUME V

Edited by *Claude S. Hudson,* National Institute of Health, Bethesda, Maryland, and *Sidney M. Cantor,* American Sugar Refining Company, Philadelphia. Academic Press, Inc., New York, 1950. xi + 322 pp. 31 figs. 53 tables. 15.5 × 23.5 cm. $6.80.

THIS fifth volume of the excellent series which is making available the recent knowledge concerning the carbohydrates holds to the same high standards of the preceding volumes. The emphasis is shifted somewhat toward the biochemical with four sections concerned with enzyme activity: Enzyme Synthesis of Sucrose and Other Disaccharides, Principles Underlying Enzyme Specificity in the Domain of Carbohydrates, Enzymes Acting on Pectic Substances, and Action of Certain Alpha Amylases. Other sections are primarily concerned with detailed and specialized aspects of carbohydrate chemistry: Applications in the Carbohydrate Field of Reductive Desulfurization by Raney Nickel, The Methyl Ethers of D-Glucose, and Anhydrides of Pentitols and Hexitols. Of somewhat more general interest are the sections on The Relative Crystallinity of Celluloses, The Commercial Production of Crystalline Dextrose, and Xylan.

In the present volume of the series Dr. Claude S. Hudson and Dr. Sidney M. Cantor take over as editors from Professor W. W. Pigman and Professor M. L. Wolfrom who so capably edited the earlier volumes. No great change of editorial policy is proposed. The retiring as well as the new editors deserve great praise for their inestimable service in making available to teachers, students, and specialists this series of "critical, integrating reviews."

IRWIN B. DOUGLASS

UNIVERSITY OF MAINE
ORONO, MAINE

FLUORESCENCE AND PHOSPHORESCENCE

***Peter Pringsheim,* Argonne National Laboratory, Chicago, Illinois. Interscience Publishers, Inc., New York, 1949. xvi + 794 pp. 219 figs. 149 tables. 16 × 23.5 cm. $15.**

FLUORESCENCE and phosphorescence are among the most fascinating phenomena to observe, for a layman and a physicist alike; and yet these fields of physics have been—and still are—rather neglected in physical training and research. (The same, incidentally, is true of photochemistry—the branch of chemistry for which fluorescence is of greatest significance.) Until the appearance of fluorescent lighting, the exploration of these areas has been left to comparatively few devotees; among them, Professor Pringsheim is easily the most distinguished and most persevering. His first papers on the fluorescence of iodine vapor appeared in 1921; they were soon followed by an important monograph "Fluorescence and Phosphorescence in the Light of the New Theory of Atomic Structure." At that time, precise study of the fluorescence of gases had acquired great importance as a means of verification and extension of Bohr's theory of spectra. For several years resonance fluorescence, sensitized fluorescence of gases and vapors, quenching of fluorescence by magnetic fields or molecular collisions, and similar topics, remained the subject of intense experimentation and theoretical analysis. Pringsheim and his pupils, and the many visitors from other countries who came to his laboratory at the University of Berlin, contributed much to the pioneering work in these fields; and Pringsheim's monograph became immediately upon its publication—and has remained ever since—the most authoritative summary of the twin phenomena of fluoresence and phosphoresence in their relation to atomic and molecular structure. As the quantum theory of atoms and simple gas molecules became "common textbook knowledge," the interest in gas fluorescence receded; and yet, today, in reading the chapters of Pringsheim's enlarged English version of the "Fluorescence and Phosphorescence," one not merely relives the thrill of 25 years ago, when Bohr's intuition suddenly threw light into previously mysterious jungles of spectroscopy, but also recognizes how many interesting phenomena have remained unexplored, how many promising threads have never been followed.

In recent years, the most active interest has been in the luminescence of solids, for two reasons. In the first place, fluorescence and phosphorescence phenomena offer useful approaches to the understanding of the electronic structure of condensed systems—of the interaction of atoms in them, the motion of electrons, and the exchange of excitation quanta. In the second place, rapidly spreading practical utilization of fluorescent light led to broadening and multiplication of research, as is usual when a previously "academic" phenomenon is recognized as the basis of economically important developments. Professor Pringsheim has acknowledged this new emphasis by enlarging considerably the second part of his monograph, dealing with condensed systems. This part now occupies 380 pages, considerably more than the 250 which are devoted, in Part 1, to gases and vapors. However, even in the field of solid phosphors the book retains the approach of a physicist with primarily scientific interest, rather than of an engineer concerned mainly with technical applications of luminescence.

It makes one somewhat nostalgic to see a slim monograph, of which workers in the field of luminescence once studied every page, transformed into a thick volume, which few will be able to read from cover to cover; but this metamorphosis could hardly have been avoided. In fact, the reviewer wishes—for personal reasons—that the fluorescence of dyestuffs (and other organic materials in solution) had been treated by Professor Pringsheim more extensively.

The theoretical sections of Pringsheim's book are presented simply and clearly, unencumbered by mathematical apparatus. That the monograph is dedicated to Professor James Franck is fitting because it shows the spirit of the latter's "Göttingen School," which, 25 years ago, pioneered in dealing with electrons, atoms, and molecules as concrete, familiar particles, rather than as imaginary entities (which they were before), or as unimaginable mathematical abstractions (which they have tended to become later).

One original feature of the monograph is worth mentioning. Instead of the conventional (and unrevealing) author's index, an extensive, alphabetically arranged bibliographical list of almost 2000 consecutively numbered references is provided at the end of the book; it is followed by a table, showing the pages in the book on which discussion of material from any given paper in the index can be found. This two-step reference system may somewhat bewilder a casual user of the book; but after a little while, one discovers its great economy and convenience.

E. RABINOWITCH

UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS

THE YOUNG SCIENTIST

***Maitland P. Simmons,* Science Department, Irvington High School, New Jersey. The Exposition Press, Inc., New York, 1951. viii + 164 pp. 35 figs. 14 × 22 cm. $3.**

THIS is a science activity text that will stimulate activity in the science classroom and the student's initiative. Mr. Simmons has tested these activities himself and designed them to give the principles of natural science through meaningful laboratory work. The equipment required for these experiments is of the kind found in the school laboratory and the illustrated directions present the activity in a clear, forceful way. Mr. Simmons is known for his enthusiasm and creative work in the science classroom. This text will afford opportunities for the young scientists in the eighth and ninth grades to catch some of this enthusiasm and apply it to their own creative work. The questions stimulate the activities.

GRETA OPPE

BALL HIGH SCHOOL
GALVESTON, TEXAS

INTRODUCTORY QUANTITATIVE ANALYSIS

Ernest H. Swift, Professor of Analytical Chemistry, California Institute of Technology, Pasadena, California. Prentice-Hall, Inc., New York, 1950. ix + 534 pp. 48 figs. 23 tables. 15 × 22 cm. $3.90.

INITIAL paging through Swift's "Introductory Quantitative Analysis" left the reviewer with a decidedly favorable impression; closer examination has strengthened this feeling. This book is excellent; the material has been carefully selected, logically organized, and presented in a clear, simple, and concise literary style. There is close correlation between the theoretical principles and the laboratory procedures. After a thorough discussion of the pertinent principles, a concise procedure is presented, followed by numerous explanatory notes. The various section headings, printed in type which really stand out, indicate careful organization and facilitate ready reference to desired information.

This book is arranged with the volumetric preceding the gravimetric work. The first four chapters, 62 pages in length cover various laboratory instructions, weighing and calibration of weights, quantitative analysis in general, the definition of certain terms, and calibration and use of volumetric apparatus. Volumetric analysis is introduced by an excellent chapter on precipitation analysis. The author states: "Precipitation, rather than neutralization, methods are first treated because precipitation phenomena lend themselves to the general introduction of mass-action principles and to the use of these principles in an evaluation of end point errors. Neutralization methods are deferred until later in the course, since experience has shown that students are troubled by the equilibria involved, especially their application to indicator selection and errors, and to titrations involving polyprotic acids." The Gay-Lussac method for silver, zinc with ferrocyanide and an external indicator, and the Liebig method for cyanide are discussed briefly, chloride by the Mohr, Volhard, and adsorption indicator method in more detail. The principles of reduction potentials are developed in a short chapter of eight pages and then applied in the chapters on permanganate, cerimetric, and iodometric (iodine and thiosulfate) methods which follow. A novel topic in this chapter is catalysis of an oxidation-reduction reaction in an homogeneous system; an example of such a catalyst is the use of iodine monochloride in the standardization of permanganate against arsenious acid. The section on acidimetry and alkalimetry includes a thorough discussion of indicators, the standardization and application of acid and base solutions. Nitrogen in an organic compound is determined by the semimicro Kjeldahl method, and ammonium or nitrate by the macro Kjeldahl distillation technique. Gravimetric methods of analysis are applied to the determination of chloride, sulfur in pyrite or sulfate, and copper and lead electrolytically. Gravimetric analysis is discussed in considerable detail in regard to solubility, factors affecting the physical characteristics of precipitates, and the composition, purity, and stability of the precipitate. Some will regret that treatment of colorimetric analysis is not included in the book. There are excellent chapters on the preparation of solutions of the sample and on separations. In the chapter on separations brief discussions of chromatography, ion exchange, and organic reagents are included.

There are some 200 problems in a section near the back of the book. Selection of problems is made easy by grouping them by subject and by the use of appropriate titles. Five pages in this section are devoted to the subject of precision, accuracy, and significant figures. Solutions of the problems and answers are being prepared for distribution to instructors using the text. No logarithm table is included. Tables of atomic weights, ionization constants of acids and bases, dissociation constants of complex ions, solubility product, and standard (molal) and formal reduction potentials add to the utility of the text.

The author still advocates in this text his logical but unorthodox system of designating concentrations which he used in his previous text, "A System of Chemical Analysis." That is, a formal solution contains one gram-formula weight of the stated compound per liter but does not indicate the specific molal or ionic species in which it exists. A molal solution contains one gram-molecular weight of the particular molecule or ion per liter of solution. However, in this text concentrations are expressed mainly in terms of normality. The author states "reagents are expressed by their normality concentration except where confusion is likely to result in which case their formal concentrations or both the normal and the formal concentrations will be given. Molal concentrations will be used in mass-action considerations where it is desired to express the concentration of some particular species or molecule as it exists in the solution."

The book is intended for use in either a one-semester or one-year course. Ample experiments are included for a year course. However the author's students are in some cases required to consult other sources for methods of analysis of some assigned substance. "The author is convinced of the advantages which accrue to the student of being required to consult other texts, reference works and the original literature once he has acquired a sufficient background of experience to be able to exercise some critical judgement in so doing." A striking feature of the book is the number of references to the recent literature and frequent footnotes commenting upon articles in the literature. The author's endeavor to encourage originality upon the part of the student is to be highly commended. The level of the book is one which should give the student an excellent training in the theory and technique of quantitative analysis. Some teachers may consider the level of the book too high for the short course, particularly for nonchemistry majors. A section of fifteen pages of lecture demonstrations is a feature which should be welcomed by both students and lecturers in quantitative analysis.

The author is to be congratulated upon the success he has attained in blending together the ever-increasing amount of theoretical principles demanded of quantitative chemistry today and the simplicity of presentation desired for the sophomore student.

REX J. ROBINSON

UNIVERSITY OF WASHINGTON
SEATTLE, WASHINGTON

PHYSICS: ITS LAWS, IDEAS AND METHODS

Alexander Kolin, Assistant Professor of Physics, the University of Chicago. McGraw-Hill Book Co., Inc., New York, 1950. xvi + 890 pp. 458 figs. 11 tables. 16 × 24 cm. $6.50.

THIS textbook has a twofold aim: to give training in physics to students in the biological sciences, and to give training in the methods of the physical sciences as one of the objectives of general education. It is organized into four parts in which the study of physics is approached in different ways, proceeding from the simple to the more abstract. In Part A, dealing with mechanics, vector fields, and heat, laws are inferred from observations. The mathematical formulation of physical laws is shown to make possible the prediction of new facts, to be then tested by experiment. In Part B, the atomic theory of electricity and matter is used to demonstrate the theoretical approach, using mechanical model theories to explain the behavior of gases, the phenomena related to electricity in motion, and electromagnetic phenomena. Part C deals with the wave theories of sound and light. Here the student is shown that mechanical models are inadequate to explain some physical phenomena. The mechanical wave theory of light is displaced by an electromagnetic wave theory. Part D deals with the emission and absorption of light, wave mechanics, radioactivity, and the theory of relativity. It becomes evident that neither mechanical models nor classical theories are adequate in these fields, but that theories devoid of pictorial character and requiring an arbitrary revision of fundamental concepts have been quite fruitful in interpreting these phenomena.

Much has been written on the theme that training in science is valuable in general education, in that those who have studied science will be more scientific in their approach to problems in other areas. Psychologists are quick to point out that such

transfer of training does not occur easily nor in quantity, although some circumstances are more favorable for transfer of learning than others. This text does not only discuss interesting and pertinent applications of physics but, through questions and problems it requires analysis of concepts and theories, the exercise of ingenuity in designing experimental methods, and the solution of quantitative problems—all of which should lead to a mastery of the subjects discussed, as well as respect for the power and limitations of the science. To the reviewer, this seems to present a favorable situation for the transfer of learning.

Much has been said, also, of the value of applying "the scientific method" to problems—*e. g.*, in the social sciences—forgetting that there is no one scientific method but that the scientific attack of problems makes use of a variety of methods, suiting the kind of method to the nature of the problem. To the student of this text it will be evident that there are a variety of methods even for a single science, the method frequently being determined by the nature of the problem or the kind of solution desired. Perhaps this will make it easier for him to appreciate that in some disciplines "the scientific method" is only of supplementary value, and that many disciplines (*e. g.*, fine arts, history, literary criticism) have their own methods, distinct from "the scientific method" and particularly suited to their own field.

The triple-point temperature for water is given as 0.0072°C. instead of 0.0098°C. (p. 246), an error which results from ignoring the effect of dissolved air on the freezing point of water. In Chapter 22 are references to *Zn* ions, SO_4 ions (even in chemical equations for electrode reactions), where it would be preferable to write Zn^{++} and SO_4^{--}. The discussion of electrolytes is as modern as Arrhenius and the student is left with the impression that molecules of $CuSO_4$ and NaCl are partly dissociated into ions in the process of dissolving them in water. On the other hand, the sections on atomic structure and on radioactivity are more informative and interesting than the corresponding discussions in most elementary chemistry texts. The discussions are easy to follow, the mathematics simple, the figures clear, and the book attractively printed.

WALTER B. KEIGHTON

SWARTHMORE COLLEGE
SWARTHMORE, PENNSYLVANIA

● NATURAL AND SYNTHETIC HIGH POLYMERS

***Kurt H. Meyer,* Professor of Chemistry, University of Geneva, Geneva, Switzerland. Second revised and augmented edition. Interscience Publishers, Inc., New York, 1950. xx + 891 pp. 184 figs. 76 tables. 15.5 × 24 cm. $15.**

THIS text and reference book, Volume IV in the High Polymer Series, is by all odds the best in the field and is a credit to the author, the editors of the series, and the publisher. It has inherited its position in the field of polymer science from its grandsire, "Der Aufbau der hochpolymeren organischen Naturstoffe," by Meyer and Mark, which, through clarity, penetration, and timeliness, won first place in the polymer libraries of 20 years ago.

The volume opens, after sauntering through a nine-page introduction, with 80 pages outlining physical and physico-chemical investigations of high polymers, laying a substantial foundation for the subsequent ten sections. Much valuable information on the physical and quantitative aspects has accumulated since the first edition. The reviewer is gratified to note in the preface, however, that ". . .warning must be given against too confident use of so-called quantitative theories that are based upon more or less inadequate models." The temptation to place great confidence in a mathematical derivation, because of its mysticism and elegance, should be consciously resisted.

The second section, devoted to inorganic polymers, is well placed near the head of the list, not because of the importance it has won but because of its potential significance for the future.

Sections follow on high polymeric hydrocarbons; polymeric ethers, esters, sulfides, etc.; cellulose; and on polysaccharides and lignin. Significant advances in these fields are being made almost daily, and Meyer discloses that he has been alert to them.

Then come 160 pages devoted to proteins, a subject well deserving of the space both due to its inherent importance and to the quality of the work being done on it.

The following two sections on properties of polymers in solution, and elasticity, viscosity, and plasticity are complementary to the opening chapter and provide with it an excellent compendium of the quantitative side of the science.

The final chapters on films, foils, and membranes, and on molecular structure of animal and plant tissues bring to a close this reference book and text that no individual seriously interested in high polymers can afford to be without.

S. S. KISTLER

NORTON COMPANY
WORCESTER, MASSACHUSETTS

● SEMIMICRO QUALITATIVE ANALYSIS

***William C. Oelke,* Professor of Chemistry and Chairman of the Department, Grinnell College, Grinnell, Iowa. D. C. Heath and Co., Boston, 1950. ix + 377 pp. 39 figs. 14 × 22 cm. $3.75.**

PROFESSOR Oelke's book "Semimicro Qualitative Analysis" introduces the students to a great deal of chemistry besides giving them the necessary directions for carrying out the laboratory work. The theory in general is well organized and good sets of problems follow each section. The discussion of equilibrium constants is very well done and should be understandable even to the poorer students. A few advanced sections, however, are more complicated and some teachers may object to the introduction of such concepts as free energy and quantum energy levels.

The laboratory directions are well done. Good explanations are given for the tests used. These include structural formulas for organic reagents. The tests seem to be selected for their workability and also for the fundamental chemistry they illustrate. Optional provision is made to include the badly neglected element titanium in the scheme.

The book is relatively free from errors. However, on page 169 there seems to be an error in the explanation of the test for oxidizing agents. The product of the reaction is a higher valent chloride rather than MnO_2. The use of the abbreviation HOAc instead of the customary HAc is very confusing.

The book provides for the analysis of 20 anions and 28 cations counting an ion for each of the two valences for Sb, Sn, Hg, and Fe. An abbreviated system is provided for both anions and cations.

Many teachers who are looking for a semimicro book will doubtless find Mr. Oelke's book very satisfactory for their purposes.

RAY WOODRIFF

MONTANA STATE COLLEGE
BOZEMAN, MONTANA

● ION EXCHANGE RESINS

***Robert Kunin* and *Robert J. Myers,* Rohm and Haas Co., Philadelphia. John Wiley & Sons, Inc., New York, 1950. xi + 212 pp. 104 figs. 30 tables. 15.5 × 23.5 cm. $4.75.**

SYNTHETIC, resinous, ion exchangers were described for the first time in 1935 by Adams and Holmes. Now after 15 years a book of 212 pages is required to summarize the properties and uses of these remarkable products.

With few exceptions the preparation of ion exchangers and their use in industrial processes have been in the hands of industrial chemists. The rapid development of this subject is a tribute to the initiative of the practical scientist. This progress and the preparation of this book by two industrial scientists illustrates the vital role of industry in the advancement of science. Acknowledgment of the helpful suggestions from the ion-ex-

change specialist of a major competitive corporation indicates a constructive scientific policy now common to many industrial organizations.

Exchange resins are remarkable for their great ion-exchange capacity, which may be nearly 1000-fold that of alumina or of silica gel. They are fashioned by organic synthesis to fill particular needs. Their insolubility, permeability, and stability are determined by the degree of polymerization or condensation of nonionizing groups such as double bonds, aldehydes, phenols, and primary amines. Their exchange properties are determined by the presence of ionizing groups, such as the sulfonic and carboxylic groups of cation exchange resins, the basic nitrogen groups of anion exchange resins, and various specific groups in selective exchange resins. All these resins are finding wide application in fundamental separatory processes such as the removal of cations and of anions from solutions, the isolation of various cations and anions from innumerable products and from living organisms, and the extensive resolution of complex mixtures by the sensitive columnar or chromatographic analysis. Their use as specific reactants is in its infancy. Owing to their dependability and uniformity, commercially prepared, ion-exchange resins have served for most theoretical investigations of various exchange phenomena.

In this monograph five chapters describe the history, the theory and mechanism, the characteristics, and the synthesis of ion-exchange resins. Five chapters illustrate applications of the resins as in water softening, in deionization of water, in analytical chemistry, and in various other processes. A particularly important chapter is devoted to the methods of studying ion-exchange resins, and a final chapter to the design of ion-exchange apparatus. The bibliography contains 615 entries.

This concise monograph covers a remarkably wide range of subject matter; hence, its appeal and its service will depend upon the reader's interest and experience. The general reader will have difficulty in gaining a clear concept of the phenomenon of ion exchange in the resins, a concept that is essential to comprehension of the first five chapters. Conscientious teachers in quest of basic concepts will find the fundamental principles of an important natural phenomenon. Curious students will find many new methods and applications that are influencing scientific advances. Engineers will find the operational principles of new widely applicable processes. Specialists looking for particular aspects of the subject will find references to all areas of investigation and application, including therapeutic uses.

HAROLD H. STRAIN

Argonne National Laboratory
Chicago, Illinois

• INDUSTRIAL ELECTROCHEMISTRY

C. L. Mantell, Chairman, Department of Chemical Engineering, Newark College of Engineering. Third edition. McGraw-Hill Book Co., Inc., 1950. x + 781 pp. 283 figs. 106 tables. 15.5 × 23 cm. $8.50.

The author's contention that electrochemistry is generally treated as a subdivision of physical chemistry is undoubtedly correct. The purpose of this book is, therefore, to rectify the situation by presenting the subject from the chemical engineering point of view. Consequently, the first part, on "Theoretical Electrochemistry," occupies a little over 60 pages, while the other parts, entitled "Technical Electrochemistry," "Electrolytics," "Electrothermics," "Electrochemistry of Gases," and "Engineering," occupy the remaining 650 pages or so of the text. In some respects the book might have been better if the theoretical section had been omitted entirely. Much of the treatment was out of date even when the first edition of the work was published in 1931.

The more technological sections of the book cover a wide variety of topics, ranging from electroplating of metals to the production of calcium carbide in the electric furnace, and from primary cells to electrical discharge in gases. Because of the large number of subjects covered, the treatment is, of necessity, somewhat superficial, although this is offset to some extent by the numerous tables, line drawings, and half-tone illustrations. Another disadvantage of the broad coverage is that the reader is often left in doubt concerning the relative importance of various processes. For example, there are descriptions and detailed tabulations of 16 types of diaphragm cells for the production of chlorine and caustic soda. Some of these are undoubtedly obsolete, or at least obsolescent, but there is little or nothing to indicate this in the text.

Because of the large amount of ground covered, and the excellent index, teachers will find this book a useful reference. It will give them and their students an idea of the tremendous scope of electrochemistry in industry that is all too frequently overlooked.

SAMUEL GLASSTONE

San Carlos
California

• METALS AT HIGH TEMPERATURES

Frances Hurd Clark, Reinhold Publishing Corp., New York, 1950. v + 372 pp. 149 figs. 133 tables. 15.5 × 23.5 cm. $7.

This "first American book on the new high-temperature metallurgy" is primarily a compilation of information recently made available on the properties of metals at elevated temperatures. Metals, being what they are, become subject variously to oxidation and plastic deformation at high temperatures, and but few meet the modest requirements of oxidation resistance, strength, toughness, and retention of shape set by engineers who design gas turbines and other modern power plants for a maximum temperature of 815°C. (1500°F.). Were it possible to elevate the sights to 1090°C. (2000°F.), there would be a marked increase in the theoretical efficiency of converting chemical energy into power, and for a given weight of fuel in an aircraft, heavier payloads or greater range of flight. The limitations are set by failure of metals to remain rigid at high temperatures; hence, the importance of gaining more information about the high-temperature properties of metals and alloys cannot be overemphasized.

Chemists are usually not so aware of the phenomenon of *creep* in metals as they are with the destructive reactions of metals with gases. If, however, in a given application, the metal can be protected from oxidation, it may still be rendered useless by a slow plastic deformation under stress. This may occur at a barely perceptible rate, but in time, due to the resulting change in shape, the part has to be replaced. It is not possible to predict creep rate from a knowledge of the room temperature properties of a metal, and creep tests of short duration at high temperatures are not reliable. It is not uncommon, therefore, to witness tests in which the length of a metal tensile specimen, kept at a constant, high temperature, is measured daily for a period of 10,000 hours. Tests must be continued for at least 10 per cent of the expected service life of a component under conditions as close as possible to those encountered in service. Such tests are very expensive and time consuming. The number of alloys to be tested is large and a single research laboratory can cover only a small fraction of possible alloys. Results of creep tests and measurement of other mechanical properties of metals at high temperatures constitute the major contribution of this book.

The author has collected recent data on high-temperature tests from both American and European laboratories on alloys varying from low carbon steel to the so-called super-alloys. The first two chapters deal in 100 pages with the theoretical aspects of plastic deformation of metals and methods for determining the mechanical properties of metals at high temperatures. Chapters 3 and 4 are concerned with low alloy steels, chromium-iron alloys, and moderately alloyed austenitic steels. Chapters 5, 6, 7, and 8 report tests on highly alloyed austenitic steels, cobalt-base alloys, nickel-base alloys, and finally, "non-commercial alloys."

The properties of a metal or alloy depend upon the microstructure, and this is greatly influenced by the method of producing and fabricating parts from them. Some alloys are so hard and brittle that they can only be molded into final shape by precision casting methods. The structure may be coarse grained as a result. Molybdenum was formerly produced by powder metallurgy methods only, but now arc-melted castings that may be forged and rolled into sheet can be made. This has resulted in improved mechanical properties at high temperatures. Alloys that are high in cobalt, chromium, molybdenum, or tungsten, the basic elements for super-alloys, that were formerly too brittle to forge, have, as a result of the ingenuity of research metallurgists, gradually become amenable to conventional fabrication methods. Each step in the process must be carefully controlled and is usually the result of much hard work that is almost entirely empirical in approach. These special manufacturing processes are discussed in Chapter 9.

In Chapter 10 low melting alloys, like those of lead, magnesium, and aluminum, which have important uses at moderately high temperatures, are given brief mention. The last chapter presents results of tests on scaling of alloys, which have been designed primarily to resist chemical attack at high temperatures, in air, steam, and controlled atmospheres. This section is of particular interest to chemists.

The increased importance of high temperatures and high pressures in fields other than superchargers, jet propulsion, and gas turbines, makes it imperative for chemists to have access to the new information contained in this book. It is a book in which they may have confidence, because Dr. Clark has been closely associated with the field for many years and has been able to secure information previously unpublished and inaccessible. For reference work there is no comparable publication.

Because it is so uncommon to encounter a woman professional metallurgist, a brief comment on Dr. Clark's career will interest teachers who are looking for fields into which to direct their able women students. Miss Clark graduated from Massachusetts Institute of Technology as a metallurgist in the class of 1922 and received her Sc.D. degree from the same institution in 1926, the only woman in her group in each instance. She won fame in the field of powder metallurgy for her work on contact-point alloys during her years at Western Union Laboratories, and she has served on the staff of the Powder Metallurgy Laboratory at Stevens Institute of Technology. She is now engaged in applied research and development, mainly in the field of her excellent book. She is a married woman devoted to her home, but for professional reasons writes under her maiden name. She has accomplished what many women desire, a successful career in science and a happy but separate private life.

LAURENCE S. FOSTER

BELMONT
MASSACHUSETTS

● PHYSICS IN CHEMICAL INDUSTRY

R. C. L. Bosworth. **Macmillan and Co., Ltd., London, 1950. xix + 928 pp. 15.5 × 23 cm. $12.75.**

THIS book is applicable to English readers more than to those in the United States where the fundamentals of the chemical industry, or preferably chemical engineering, are handled in a different manner. The contents of this volume can be better understood in the U. S. A. by calling it a book on physics and physical chemistry. It is instructive to see how another group of scientists approach this subject, and as such this work by Bosworth has a definite comparative value.

Within the 928 pages of the book here reviewed there are considered many aspects of the underlying sciences for the chemical industry. These include not only physical chemistry but some of the purely physical aspects of unit operations, the chemical changes such as kinetics, equilibrium and the like, as well as mathematics and instrumentation. Part I (Chapters 1–7) embraces a "Mathematical Introduction" and treats the mathematical concepts and their application in "Dimensional analysis" (Chapter 5) and "Statistical methods" (Chapters 6 and 7). Part II (Chapters 8–17) considers under the heading "Properties of Matter" both physical and chemical changes such as equilibrium, gases, solids, absorption, physical metallurgy, etc. In Part III, or "Movement of Matter," is included a fundamental study of motion, diffusion, energy, radiation, and rate of chemical reaction. Part IV, "Scientific Instruments," embraces what in the United States is called instrumentation.

The author has accomplished a Herculean task to include such a variety of subjects within one volume. The treatment is basically mathematical and is supplemented by end-of-chapter references to books and journal articles. The book is well written with nice illustrations, excellent printing, and on very satisfactory paper. Regretfully the reviewer must state that the American reader will do much better to spend his time on the many other books covering the various subjects here presented (Perry, *Editor*, "Chemical Engineers' Handbook" and its very many references).

R. NORRIS SHREVE

PURDUE UNIVERSITY
LAFAYETTE, INDIANA

● SOILS: THEIR PHYSICS AND CHEMISTRY

A. N. Puri, **Director, University Institute of Chemistry and Field Research Station Trust, Lahore, India. Reinhold Publishing Corp., New York, 1949. xv + 550 pp. 179 figs. 243 tables. 16 × 24 cm. $7.**

IN THE preface the author states, "It must be understood that the material has been written for beginners, and it is not intended to be a treatise. Facts have been stated and theories have been left in the background, for theories confuse the novice and tax even the initiated."

Part I, "Chemistry of the Soil," treats the soil as an acidoid which does not differ from an ordinary acid. The author believes the electronegative part of the soil acidoid can be completely disregarded. The titration curves of soils with various bases are given considerable attention. Interaction of ammonia, carbonates, and sulfides with soil acidoids is considered. Hydrogen ion activity, heat of neutralization, relation of specific surface and chemical reaction, and effect of ignition are discussed in separate chapters. Active mass is defined as "that portion of the total weight which constitutes the monomolecular layer." The author believes that the active mass is as much in true solution as any common molecular solution. Thus, in considering reactions the molecules which do not constitute the surface of a colloid can be disregarded. The occurrence and importance of clay minerals in the chemical and physical properties of soils, and the origin of exchange charges on the different clay minerals are not discussed. Quality of irrigation waters, electrodialysis, dispersion of sodium saloids, oxidation-reduction potential of soils, action of carbon dioxide on soils, interaction between anions and soils, oxidation of nitrites and oxalates in soils, physiochemical properties of ferro-alumino-silicates, and humus are also discussed.

Part II covers the mechanical analysis (particle-size distribution) of soils. Emphasis is placed on apparatus and methods, many of which were developed by the author. A method for pipetting particles 40 mμ (0.00004 mm.) in diameter with a hypodermic needle at 1 mm. after settling one week is described. The effect of convection currents and the platy nature of clay of this size are not discussed. The relation of mechanical analysis to specific surface is discussed in detail. No mention is made of the differences in specific surface of the different clay minerals commonly found in soils. Physical characteristics of soils related to mechanical analysis are discussed. Chemical reactivity can also be calculated from the mechanical analysis.

Part III concerns soil moisture. The hypothesis of capillary condensation is accepted as the mechanism of moisture absorption by soils. The vapors are condensed as bulk liquid in pores by

the lowering of vapor pressure brought about by surface-tension effects. From mechanical analysis the size distribution of the pores can be calculated and the relation between relative vapor pressure and moisture content can be worked out. This assumes a roughly spherical shape for the particles, which has not been found to be true by direct examination of clays. The "capillarimeter" is used to determine the moisture sorption at various applied tensions ("pressure deficiency"). Percentage saturation is plotted against pressure deficiency. The curve is related to that calculated from mechanical analysis and thus to the pore size.

The book is based primarily on the author's own research. Only slight mention is made of other work and in most cases direct literature citation of both the author's and other work is omitted. Among the important aspects of soil chemistry not covered are the determination of availability of plant nutrients, fixation of phosphorus and potassium, and mineralogical analysis of soils. Availability of soil moisture to plants and soil structure is not covered. In the 243 tables of data the many soils under study are referred to only by number with no reference as to location, color, texture, organic matter content, or other properties. Thus it is impossible to correlate the results with other soil properties. Some of the graphs are difficult to read. The book is rather empirical in nature and would tend to confuse the beginning student in soils. The lack of reference citation and omission of other work would also limit its use as a reference book.

WALLACE Z. MACKIE

U. S. Department of Agriculture
Beltsville, Maryland

● THE POLAROGRAPHIC METHOD OF ANALYSIS

O. H. Müller, Associate Professor of Physiology, State University of New York Medical Center, Syracuse, New York. Second edition. Chemical Education Publishing Co., Easton, Pennsylvania, 1951. xii + 209 pp. 51 figs. 10 tables. 13 × 20 cm. $3.50.

This is the second edition of a well-known text in the Contributions to Chemical Education Series. As in the first edition, published in 1941, the authors stated the purpose is "to present a simple account of polarography in a form which can be used by teachers and students of physical chemistry as well as in advanced courses in analytical chemistry."

The material covered and its arrangement in the book make it well suited for use as a text. Polarography is developed, in Chapter I, as a special branch of the more general field of electroanalytical chemistry.

Polarographic apparatus is described in Chapter II. Details for the construction and operation of a simple, inexpensive, yet adequate manual instrument are given. Many of the current-voltage curves used as illustrations in the book were obtained with an instrument of this design and all of the 26 suggested experiments can be performed with it. The principles of recording polarographs are discussed but details of commercially available instruments are omitted.

The quantitative and qualitative aspects of polarography are brought out in Chapters III and IV. The suggested experiments in both of these chapters are well designed and provide an excellent practical demonstration of the variables that must be considered if the polarograph is to be used as a precise analytical tool.

Much of the material of the first four and the seventh chapters has been carried over from the first edition. However, much new material has been added, illustrative of the developments in the field during the ten years separating the two editions.

Chapters V, VI, and VIII are new in this edition. In the first of these, Polarometry, the uses of the dropping mercury electrode for purposes other than to obtain current-voltage curves, are discussed. Included are the techniques of "polarometric titrations" and the use of the dropping electrode in the study of reaction kinetics.

An extremely useful addition to the present volume is Chapter VIII, entitled Suggestions for Practical Polarography. The discussion of the capillary constant and the radius of the capillary orifice together with the author's plea that m and t data be included in reports of polarographic investigations should be read not only by teachers and students but also by "advanced practitioners" in the field.

The book should be a welcome addition to the literature by all interested in the practice and teaching of this modern method of chemical analysis.

DAYTON E. CARRITT

The Chesapeake Bay Institute
The Johns Hopkins University
Baltimore, Maryland

● CHEMICAL THERMODYNAMICS

Irving M. Klotz, Professor of Chemistry, Northwestern University. Prentice-Hall, Inc., New York, 1950. xiii + 369 pp. 15.5 × 23.5 cm. $6.

Presented from the "classical" standpoint, this textbook is a worthy attempt at a consistent exposition of thermodynamics.

The numerous concrete examples should be welcome to most students. However, a few things in the book may be confusing to some readers. Terms are not clearly defined as they are used; the word *system* is introduced without ever being defined.

Another common source of confusion is repeated in this book: the failure to make a clear distinction between a given spontaneous change and the various methods (processes) by which it may be carried out. For example, on page 119 it is stated that a process which may occur spontaneously is *not* reversible. Then, with the reaction between hydrogen and chlorine as an illustration, the rest of the page is devoted to showing how the change *may* be carried out reversibly.

Actually, the formation of one mol of hydrogen chloride is a spontaneous *change* (not a process) which, under the same initial and final conditions, always has the same $-\Delta F$ associated with it. However, the change may be carried out by an infinite number of processes (methods), one of which is theoretically reversible. The other processes are irreversible.

Despite these minor flaws, which an instructor using the book could easily correct, the text, as a whole, is well written and should give good service in class.

W. F. LUDER

Northeastern University
Boston, Massachusetts

● COLLOID CHEMISTRY. VOLUME VII

Collected and edited by *Jerome Alexander*. Reinhold Publishing Corp., New York, 1950. xi + 736 pp. 15.5 × 23.5 cm. $15.

This volume of the well-known series edited by Alexander is a curious collection of good and bad, relevant and irrelevant essays. Some represent serious efforts on the part of the authors to make substantial contributions to the colloid chemical literature, some are perfunctory rehashes of subjects better treated elsewhere, and at least one is an effort to stake a claim as a charter member and contributor in a field that has grown away from and left the author far behind.

In general, it is the reviewer's opinion that the book could not readily be used as a text, and as a reference work would have been materially improved by a substantial reduction in the number of topics covered and a corresponding elaboration of the subjects retained. Some chapters would appear more appropriate as articles in a current periodical.

The volume is divided into three main parts: "Theory and Methods," "Biology and Medicine," and "Technological Applications."

In Part One, Chapters 1, 7, and 11 are either out of place in this volume or rambling and best left unsung. Chapter 8 by Doolittle on Newtonian flow is probably the foremost contribution and is well worth reading by every serious student of solvent action. Other subjects well handled are light scattering by inhomogeneous materials (unfortunately too limited in outlook), the role of the electric double layer, the depth of a surface, and paper chromatography.

It would seem that regardless of what subjects might be treated in Part Two there would be colloidal aspects, yet the treatment of genes and biochemical reactions and that of the tubercle bacillus are colloidal only by association, and the 52 pages on dental caries belong to the subject only through occasional mention of enzymes. To the colloid chemist the most significant subjects dealt with in this part are complexes of ions with proteins, adaptive formation of enzymes, the interaction of drugs and enzymes, and surface chemistry and biology.

Part Three on technological applications contains 21 chapters, the principal criticism of which is that they tend to be too brief or limited in outlook to be substantial contributions. The reviewer believes that the chapters on cellophane, protective wrappings, and packaging have not justified the space taken, and several others are on the doubtful list. Especially to be remarked upon among the better chapters are the treatments of rubber reclaiming, sonic agglomeration of carbon black, organophilic clays, oil well treatment, detergents, textile fibers, and photosensitive glass.

S. S. KISTLER

NORTON COMPANY
WORCESTER, MASSACHUSETTS

● CRYSTAL GROWTH

H. E. Buckley, **Head of the Crystallography Department, The Victoria University of Manchester, England. John Wiley & Sons, Inc., New York, 1951. xvi + 572 pp. 88 plates. 169 figs. 31 tables. 14.5 × 22 cm. $9.**

THIS is a fascinating and amazingly complete book, and is clearly a labor of love by one well versed in his field. Over 600 references to the original literature, including many very obscure sources, testify to the thoroughness of the coverage. While it is true, perforce, that most of these references are for the period before 1940 and the war, some are as recent as 1949. The book is profusely illustrated, as one can see from the listing above, and the illustrations are well chosen, very clear, and to the point.

While the style of writing is somewhat formal, the material is well presented and the degree of lucidity is high even to a reader unfamiliar with the field. It is made quite clear throughout the book that, in its current state, the study of crystal growth is an art and not a science. Some scientists may be annoyed that this approach permeates all the discussions so thoroughly, but such would seem inevitable at the present stage of development. This weakness, if such it be, is even enmeshed in the theoretical and mathematical discussions which are presented primarily from the historical approach, and are currently in such a state that no definitive answers are possible for most of the theoretical problems raised.

One has the feeling, on reading the book, that its biggest service is to bring together the majority of current information at a rather critical juncture when this information is almost sufficient to allow a transformation of the study of crystal growth phenomena from an art to a science. Such a collection may well serve to clarify the field and, by presenting the material in handy form, encourage sufficient new thinking that some of the problems may soon be brought much closer to solution.

In spite of the high price it would seem quite essential that this volume be made part of every science library and that its contents be known by any scientists (chemists, physicists, biologists, geologists, all included) who wish to discuss or experiment with the growth and disappearance of solid phases with any thoroughness. The practical applications to the field of industrial chemistry are equally valuable.

J. A. CAMPBELL

OBERLIN COLLEGE
OBERLIN, OHIO

● ENCYCLOPEDIA OF CHEMICAL TECHNOLOGY VOLUME VI: EXPLOSIVES TO FURFURAL

Edited by *Raymond E. Kirk* and *Donald F. Othmer,* Professors and Heads, Departments of Chemistry and Chemical Engineering, respectively, at the Polytechnic Institute of Brooklyn. The Interscience Encyclopedia, Inc., New York, 1951. xvi + 1008 pp. 19 × 27 cm. $20.

THE half-way mark has been reached by this encyclopedia with the appearance of Volume VI. It is hard to believe that half of our chemical knowledge is compressed into the first six letters of the alphabet, but if the set should be expanded to contain the remaining twenty letters, the chemical profession will be the gainers.

The subjects covered in this volume are largely industrial in nature, except for a few sections. The inorganic chemist will immediately seek the section on fluorine (10 pages) and its inorganic compounds (70 pages). The organic chemist will be interested in the organic fluorine compounds (34), the Friedel-Crafts reaction (9), fatty acids (126), formaldehyde and formic acid (24). The chemical engineer will study the sections on extraction (48), film theory (28), filtration (24), flotation (18), and fluid mechanics (41).

Leading sections in industrial topics are explosives (91), fats (31), and fatty acids (126), fermentation (58), fertilizers (76), fibers, (23), fire prevention and extinction (11), fire resistant textiles (15), fish and shellfish (10), flavors and spices (13), food and food processing, food analysis, and food chemicals (60), forensic chemistry (8), fuels (91), fungicides (10), furfural and furan compounds (12).

As usual, the material is up to date. Thus in the section on fuels one finds a subsection on jet propulsion fuels, an authoritative discussion of the synthetic liquid fuels processes including the Hydrocol process.

The necessity of a set of the encyclopedia in every chemical library becomes more apparent as the number of volumes increases.

KENNETH A. KOBE

UNIVERSITY OF TEXAS
AUSTIN, TEXAS

Two New Texts in Organic Chemistry!

by Carl R. Noller

Professor of Chemistry
Stanford University

Published in July

. . . for the standard basic course

● TEXTBOOK OF ORGANIC CHEMISTRY

Here is a modern new textbook for the standard full-year course in organic chemistry. In remarkably clear fashion, it covers the material usually considered in such a course—*plus* the following features:

1. Considerable emphasis on current explanations of the *mechanisms* of organic reactions. Although of a theoretical nature, these discussions are on a level that the average student can understand.
2. More attention than usual given to industrial uses of compounds.
3. Particularly careful organization—the student is introduced to the subject matter gradually, logically, and thoroughly.

The book is a careful abridgment of Dr. Noller's *"Chemistry of Organic Compounds"* (described below). Supplementary, advanced material considered unnecessary for the standard basic course has been omitted in a manner that leaves no break in logic or in teaching continuity.

643 pages, 6" x 9¼", illustrated. $5.75 *New*

Published in May

. . . for the rigorous basic course

● CHEMISTRY OF ORGANIC COMPOUNDS

This text is truly comprehensive—it is designed for the *intensive* first-year course. In addition to all the material found in the shorter book (described above), it includes many more compounds and a great deal on *mechanisms* of reactions; on the history, practical applications, and economic importance of compounds; and on special topics of current interest.

885 pages, 6" x 9¼", illustrated. $7.00. *New*

● W. B. SAUNDERS COMPANY

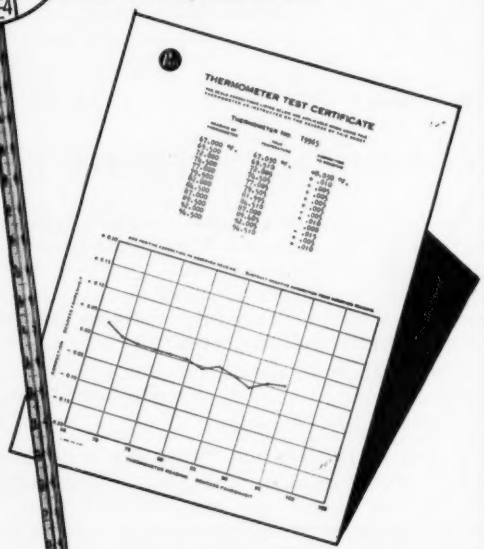
West Washington Square Philadelphia 5

PARR

Calorimetric THERMOMETERS

For reliable measurement of bomb calorimeter temperatures, and for other laboratory tests.

These are etched, solid-stem, mercurial thermometers, approximately 23 inches long, made to rigid A.S.T.M. and Parr specifications.



Parr calorimetric thermometers are individually checked against a certified platinum resistance thermometer under carefully controlled conditions. The scale corrections thus determined are reported on a test certificate supplied with each instrument.

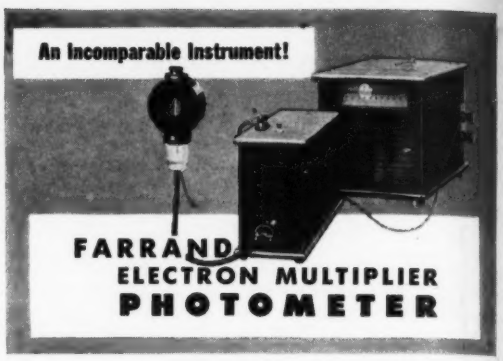
Available in both Fahrenheit and Centigrade ranges with either Parr or NBS certification.

Parr No.	A.S.T.M. No.	Range	Subdivisions
1601	56F-49T	66 - 95 F.	0.05 F.
1602	——	65 - 105 F.	0.05 F.
1603	56C-49T	19 - 35 C.	0.02 C.
1611	56F-49T	66 - 95 F.	0.05 F.
1613	56C-49T	19 - 35 C.	0.02 C.

Numbers 1611 - 1613 certified by N.B.S.; others by PARR.

Order from your Parr Dealer, or write direct to the factory.

Parr INSTRUMENT COMPANY
MOLINE, ILLINOIS
EST. 1899
MAKERS OF CALORIMETERS AND PRESSURE REACTION EQUIPMENT



Enables critical measurements which generally cannot be accomplished with ordinary photometers.

Designed for measurements at very low light levels. The detecting unit is comprised of a photomultiplier tube of exceptionally high amplification and regional response. The control unit consists of a stable battery power supply enabling a wide range of sensitivity selection, linear response and dark current balance. Arranged for easy attachment to various instruments.

BULLETIN #104 ON REQUEST

PRECISION OPTICS, ELECTRONIC AND SCIENTIFIC INSTRUMENTS

FARRAND OPTICAL CO., Inc.
BRONX BLVD. and EAST 238th STREET · NEW YORK 70, N. Y.

COLEMAN
Certified
BUFFER TABLETS
always fresh, always accurate

PRECISE . . . Coleman Buffers are accurate, because they are always *fresh*. These dry tablets can't deteriorate and change pH as liquids do . . . Certified Buffer Tablets are accurate to 0.02 pH at all times . . . available from 2.00 pH to 11.80 pH in steps of 0.20 pH . . . each tablet makes 100 ml of buffer.

CONVENIENT . . . You can store a wide range of Buffer tablets in a small space . . . have fresh, accurate buffer always at hand.

ECONOMICAL . . . Low initial cost, and freedom from spoilage make Coleman Certified Buffer tablets the economical, *dependable* way to use buffers.

For full details write for Bulletin BB-205

COLEMAN INSTRUMENTS 318 MADISON ST. MAYWOOD, ILLINOIS

WE RECOMMEND

DRIERITE

"The Versatile Desiccant"

For Drying

SOLIDS—LIQUIDS—GASES

For seventeen years serving the

INSTITUTIONS—INDUSTRIES
LABORATORIES—PLANTS

in the solution of their drying problems

Efficient — Dries all organic liquids instantly in liquid or vapor phase. Gases retain only 0.005 mg. H_2O per liter.

Versatile — An all-purpose desiccant.

Non-Wetting — Does not become wet on saturation, nor crystallize to walls of tubes, towers or desiccators.

Neutral — Dries without reacting with either acid or alkaline materials.

Inert — Except toward water. Does not decompose, polymerize, or catalyze organic substances by contact. Insoluble in organic liquids.

Regenerative — Repeatedly after any normal use, by dehydration at 235 to 250° C.

Economical — Lowest priced high grade desiccant. Available in quantity for Industrial Processes.

References

(1) Ind. Eng. Chem. 25-653 (June, 1933)

(2) Ind. Eng. Chem. 25-1112 (Oct., 1933)

(3) National Bureau of Standards Journal of Research 12-241 (Feb. 1934, R.P. No. 649)

Granule Sizes: 2, 4, 6, 8, 10-20 and minus 20 mesh.

Write for literature and quotations

W. A. Hammond Drierite Company
120 Dayton Avenue, Xenia, Ohio

NEW ALL PURPOSE THICK LEAD PENCIL WRITES ON MOST EVERYTHING

For Marking On

CELLOPHANE,

GLASS,

CHINA,

PORCELAIN,

METAL,

LEATHER,

AND

RUBBER.

Put thick china-marking lead in it and use it for marking prices, code identification and other similar marking. Put thick crayon lead in it and use it for checking, labeling and other clerical tabulation requiring thick colored lead. Loaded with thick graphite lead it is an editorial pencil for newspaper work, advertising copy and layout, and any type of scribing requiring a heavy mark.

Pencil G 920 . . . . . 25¢ each
Refills (box of 4) . . . . . 15¢ each

GENERAL LABORATORY SUPPLY COMPANY
Apparatus and Chemicals for Industry and Science

Matheson

Gas Mixtures

We can furnish accurate mixtures of any of the 80 gases listed in our catalog. We have a department in our plant exclusively engaged in this operation with special emphasis on gases for Geiger counters, Baker-Brunjes furnaces, forming gases, duplication of various natural gases and atmospheres. Accuracy is guaranteed to be plus or minus 1% by volume, but usually approximates plus or minus ½ of 1%.

Mixtures are made to order, but can be delivered in 5 to 6 days. They are available from our East Rutherford plant in all sizes of cylinders except the lecture bottle.

Pure Organic Chemicals

Over 2500 organic chemicals stocked for immediate delivery. Included are all the building blocks needed by the chemist in industry, the research laboratory or the university.

The purity of each Matheson organic chemical is guaranteed by our strict laboratory controls.

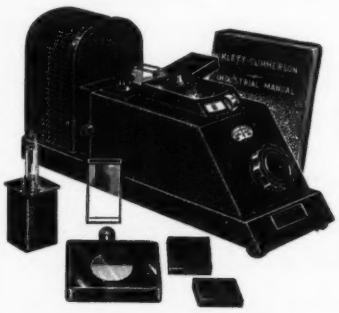
If you do not have our Price List No. 9 in your files write for a free copy.

THE MATHESON CO., INC.
EAST RUTHERFORD, N. J. JOLIET, ILL.

Klett . . . .

Photometers

Klett-Summerson



Photoelectric Glass Cell Colorimeter

No. 900-3

The Klett Fluorimeter

No. 2070

Designed for the rapid and accurate determination of thiamin, riboflavin, and other substances which fluoresce in solution. The sensitivity and stability are such that it has been found particularly useful in determining very small amounts of these substances.

KLETT SCIENTIFIC PRODUCTS

ELECTROPHORESIS APPARATUS • BIO-COLORIMETERS
GLASS ABSORPTION CELLS • COLORIMETER NEPHELOMETERS • GLASS STANDARDS • KLETT REAGENTS

Klett Manufacturing Co.
179 EAST 87TH STREET, NEW YORK, N. Y.

Out of the Editor's Basket

Automatic Titrator

The Beckman Automatic Titrator has been introduced by Beckman Instruments, Inc., South Pasadena, California. This instrument handles various types of titrations, including neutralization, oxidation-reduction, precipitation, etc. In a series of titrations, it is only necessary to fill the buret and place the sample in the beaker. The circuit anticipates the approaching end point, reducing delivery until it is reached, when it automatically stops and a light shows completion of the titration.

Projection of an Arrow

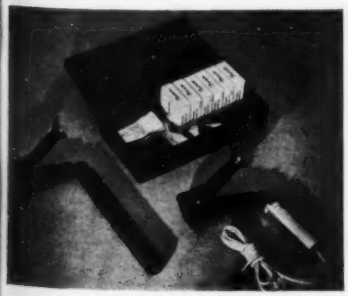
The EdnaLite Optical Co., 103 North Water St., Peekskill, New York, has perfected a projection pointer which enables a lecturer to cast a microsharp, clear, color-free, arrow-image the full length of

an auditorium while simultaneously operating the projector. The instrument produces no halations and does not interfere with the definition or color of the subject matter. It operates on 115 volt a. c., with a built-in transformer.

NEW BLACK LIGHT SOURCE

Individual visual study of the fluorescent properties of a wide range of substances under ultraviolet light, in the classroom, laboratory, and on field trips is made possible by the newly developed Menlo Fluoretor black light source.

A completely portable instrument weighing less than two pounds, the Fluoretor has a patented dark chamber in which materials are observed. Its use anywhere, regardless of outside light conditions, thus is made possible. Interchangeable end caps adapted to liquids, dusts, or solids extend its usefulness into such fields of study as geology, biology, mineralogy, chemistry, ceramics, medicine, sanitation, metal materials, etc.



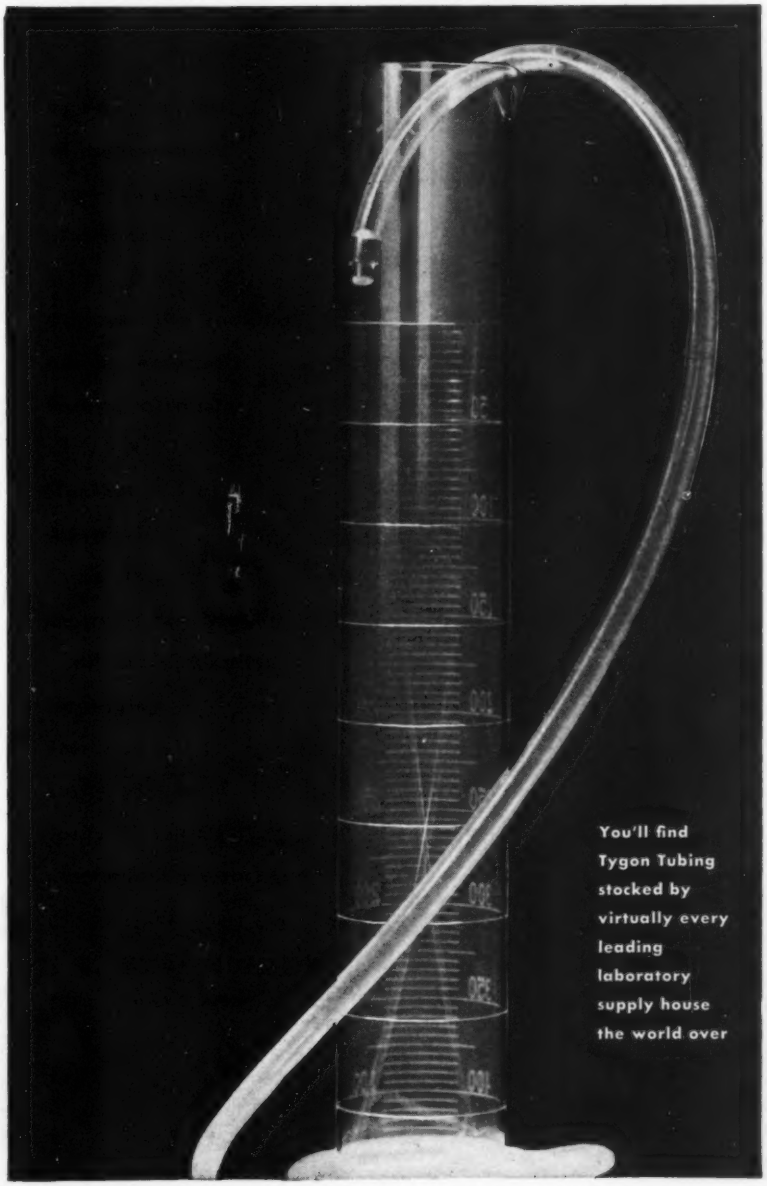
Producing ultraviolet radiation at either 2537 or 3650-63 Angstrom units, with interchangeable u-v generator units, the Fluoretor is powered from two standard flashlight batteries, with operating life in excess of 3 hours of continuous radiation. (Another model is available for operation from a 60-cycle, 115-volt outlet.) The light-tight dark chamber, into which the ultraviolet radiation is projected, is fitted with a focusing eyepiece providing three-power magnification.

Standard Fluoretor model includes six detachable end caps with various types of mountings, including test tubes, special fitting for micro slides, etc. For study of natural formations or other irregular surfaces, a sponge-rubber sleeve is provided to exclude light between the open housing and subject.

Literature can be obtained on request from the manufacturer, Menlo Research Laboratory, Box 522, Menlo Park, Cal.

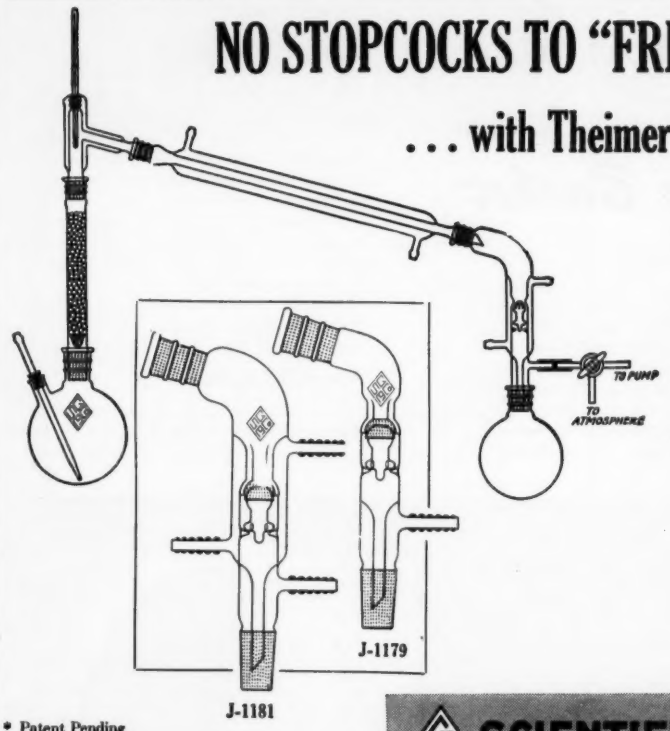
Microphotometer

A photomultiplier microphotometer for the precise measurement and comparison of light intensities from 20 micro-microlu-



NO STOPCOCKS TO "FREEZE" OR MANIPULATE

. . . with Theimer Vacuum Distilling Adapters*



Instead of using the conventional four stopcock arrangement, this vacuum distilling set-up utilizes a "Pyrex" Theimer Vacuum Adapter. Thus the problem of leakage and "freezing" is eliminated, operation is simplified, and only one adjustment is required—by means of a permanent, 3-way stopcock in the vacuum system, *removed from contact with the distillate.*

Insert shows both the jacketed and non-jacketed type adapters with serrated hose connections and "No-Chip" male joints. Note the hollow glass check valve (semi-ball type) which maintains the vacuum in the distilling unit while the fraction receiver is removed. It's automatically lubricated by the distillate . . . requires no periodic regrinding. *Full information on request.*

	24/40	29/42	34/45
No. J-1179 Theimer Vacuum Adapter—non-jacketed (specify joint size), each	**$10.00**	**$11.00**	**$12.50**
No. J-1181 Ditto but jacketed, each	**$15.00**	**$16.00**	**$17.50**

* Patent Pending

SCIENTIFIC GLASS APPARATUS CO., INC.
BLOOMFIELD - NEW JERSEY
LABORATORY APPARATUS - INSTRUMENTS - CHEMICALS - GLASSWARE

S&S

In Order To Serve You More Efficiently—

S&S

we have now consolidated our manufacturing plant, laboratories, sales and executive offices, in one large, modern, building at

KEENE, NEW HAMPSHIRE

where all correspondence, orders, shipments will be handled.

The selection of this location was due mainly to the ample supply of very pure water for treating and processing our analytical filter papers, to the dustfree atmosphere and the clean, reliable New England labor.

We hope that we shall have the pleasure of serving you from Keene and assure you of our best attention to your individual requirements.

Carl SCHLEICHER & SCHUELL Co.

Analytical Filter Papers of High Quality—Industrial Filter Papers to Meet All Requirements of Plant Processing Work—Special Papers for Use in Biological Procedures—Ultra Filters for the Filtration of Colloids, Albumen, Bacteria, Virus—Special Membranes for Dialysis, Osmosis and Osmotic Measurements in Molecular Weight Determinations.

KEENE, NEW HAMPSHIRE

mens to 20 lumens at selected wave lengths has been announced by the American Instrument Co., Silver Spring, Maryland. Its applications include: film densitometry (color, radiation, black-and-white), colorimetry, turbidimetry, fluorimetry, light scattering, scintillation efficiency of phosphors, specular and diffuse reflectivity, opacity, glossimetry, luminescence, and measurement of light intensities at selected wave lengths through a microscope, polariscope, spectroscope, etc.

Complete details are given in the manufacturer's Bulletin 2190.

Polyethylene and Vinyl Pump

The Vanton Pump Corp., Empire State Building, New York City, has just announced the availability of its new P Series of noncorrosive and noncontaminating pumps in which the fluid transferred comes in contact only with a Polyethylene Body Block and a vinyl "flex-i-liner."

This pump is said to be unique in its ability to withstand the extreme corrosive action of acids such as sulfuric, hydrochloric, nitric, and hydrofluoric, as well as caustics and other chemicals to which polyethylene and vinyl are resistant. Since there is no danger of contamination with a lubricant, oil or grease, or contact with metal, the pump is also ideal for pharmaceutical, biological, and other sanitary applications.

Because of the pump's inherent high vacuum, it is particularly well suited for gas sampling and will successfully resist corrosive gases. In addition to polyethylene, other standard Vanton Pump Body Blocks may be obtained in Bakelite or Bakelite with graphite filler. In addition to the vinyl "flex-i-liner," natural rubber, pure gum rubber, Hycar, Perbunan, and Neoprene "flex-i-liners" are available. All Body Blocks and "flex-i-liners" are interchangeable.

Glass Tubing Cutter

An electric instrument—No. 13990 Hot Wire Cutter—for cutting glass tubes of large diameter, whether of borosilicate or soft glass, has been designed by the Central Scientific Co., 1700 Irving Park Road, Chicago 13, Illinois. The instrument operates like a pair of tongs. It clamps a wire around the tube, applying sudden heat. Then a dash of cold water effects the cut.

Aloes Versus Bombs

A new ointment for the treatment of burns, known as A-Gic Gel, has been made from the juice of freshly plucked leaves of the Aloe Vera plant.

This ointment, developed by Cargille Scientific, Inc., 118 Liberty Street, New York 6, New York, causes rapid healing of the skin in cases of fire, X-ray, acid, and alkali burns. Dense white scarred tissue is not present after healing, and the burned areas remain smooth and pliable. It also has antiseptic, enzymotic, astringent, and analgesic properties. Besides its obvious usefulness in the laboratory, it is expected to be a good treatment for burns resulting from A-bomb explosions.

Bright Lamp

The "Bright-Beam" lamp, manufactured by Lindly & Co., 80 Herricks Road, Mineola, Long Island, New York, is an adaptation of their all-purpose microscope lamp, specially designed for stereoscopic microscopy and the illumination of opaque materials such as minerals and metallurgical specimens.

A small, bright burning bulb which can be obtained from photographic supply stores, is the source of light. Due to the unusual type of two-lens condensing system and reflector a spot is produced of maximum intensity, free from shadows and bright spots. The intensity of the light is varied by altering the size of the spot.

Kewaunee 3602 FUME HOOD

NOW IN FULL PRODUCTION

order now for PROMPT DELIVERY

Developed especially for radioisotope laboratories. Design approved for use by Oak Ridge Institute of Nuclear Studies. Stainless steel interior and working surface. Bonderized cold rolled steel exterior. Famous Kewaunee quality throughout. For full descriptive information, ask any Kewaunee representative for a copy of our new "*Radioactive Equipment*" folder. Or write us direct.

Representatives in principal cities

We also manufacture wood and metal laboratory equipment

Kewaunee Mfg. Co.

5014 S. Center Street, Adrian, Michigan

there's an
E&D
FILTER PAPER
for most filtration problems
of science or industry

As manufacturers of filter and absorbent papers we gladly place at your disposal our experience and skill in helping you select the proper paper for the problem confronting you. Or, if a new kind of paper is indicated, chances are we can produce it for you. Call on us without any obligation.

The EATON-DIKEMAN Co.
"MANUFACTURERS OF FINE FILTER PAPERS"
Mt. Holly Springs, Pa.

The familiar C & B trademark is your assurance that the product carrying this mark

(1) has been manufactured to meet the standards and specifications stated upon the label

(2) has passed our specifications prior to packaging and has been rechecked after packaging

(3) is backed by an organization which, for over thirty years, has had as its primary aim the production of Laboratory Reagents of the highest purity.

C&B Products are distributed by Laboratory and Physician Supply Houses Throughout the World

Write for copy of our catalog

THE COLEMAN & BELL CO., Inc.,
Manufacturing Chemists : Norwood, Ohio, U.S.A.

COLEMAN & BELL

Nations unite
in praise of —

DISCOVERY of the ELEMENTS

by Mary Elvira Weeks

Chimie & Industrie — Paris
"For a chemist or more generally for any scientific and cultured person, this volume provides entrancing reading . . . . profusely illustrated and provided with a very rich bibliography. Such a work shows in a striking manner the international character of science."

The Chemical Age — London
"This admirable survey of chemical history makes fascinating reading. The chemists, ancient and modern, are made to seem alive. . . . The completely international nature of science and the friendly relations between chemists of different nations stands out strongly."

Lychnos (Annual of Swedish History of Science Society) — Uppsala
"Of interest to Swedish readers is the biography of the de Elhuyar brothers . . . . and, above all, the chapter on J. A. Arfwedson, who at a very early age attracted attention by his discovery of lithium."

Chemiker-Zeitung — Berlin
"The chemical elements have herein found their Homer who presents the story of the discovery of the elements, old and new, in a vivid panorama of prose and through a notable collection of portraits, apparatus drawings, facsimiles of autographs, and the like. . . . Of this work one can say with justice and authority that it will stimulate not only the historical but also the experimental chemist who reads it."

The Scientific Monthly — Washington
"The book can be enjoyed with equal pleasure by the young and old. . . . For the beginner in science there are few books more suitable for collateral reading, with its fascinating and stimulating accounts of how perseverance, or intuition, or accident, has contributed to the making of some discoveries, and of how lack of caution, or over-caution, has prevented some investigators from achieving the fame of discovery. To older readers the book will be a veritable treasure-trove of scientific information. The wealth of references at the conclusion of each chapter will be a useful guide to librarians and to those desirous of enriching their collections with the rarer works on the history of chemistry. The typography of the volume is excellent."

New Technical Books — N. Y. Public Library
"A skillfully arranged history . . . . highlighted with incidents from the biographies of scientists, and illustrated with more than 300 photographs and other reproductions."

Journal of the A.M.A. — Chicago
"Everyone active in scientific fields is interested in various phases of history. The discovery of the elements provides no exception. Physicians, chemists, and others enjoy this book. It is useful in any library but has added value for teachers, research workers, and the like."

578 pages **$4.00**

Journal of
CHEMICAL EDUCATION
Easton, Pennsylvania

Please

WHATMAN

Filter Papers Are Readily Available

All dealers in laboratory supplies carry WHATMAN Filter Papers in stock to care for their normal demands.

To reinforce these stocks, we maintain a large reserve in New York upon which your dealer can draw on a moment's notice to supply items not regularly ordered or unusual quantities of standard grades and sizes.

Wherever you are, you can be sure of prompt delivery of WHATMAN Filter Papers, the uniformly reliable papers upon which so many chemists have standardized.

Should you require samples, especially for paper partition chromatography, write direct to us.

H. REEVE ANGEL & CO., INC.

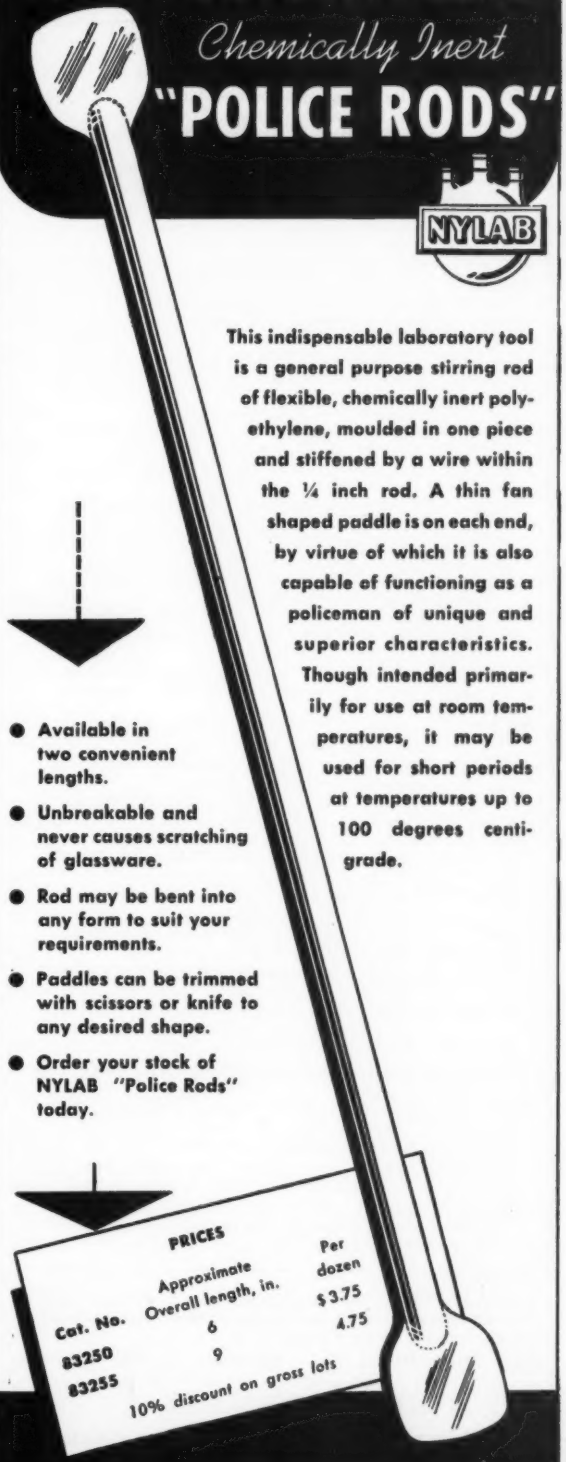
52 Duane St. New York 7, N. Y.

WHATMAN High Grade FILTER PAPERS

GET THE HABIT OF USING

THE POLYETHYLENE *Chemically Inert* "POLICE RODS"

NYLAB



This indispensable laboratory tool is a general purpose stirring rod of flexible, chemically inert polyethylene, moulded in one piece and stiffened by a wire within the ¼ inch rod. A thin fan shaped paddle is on each end, by virtue of which it is also capable of functioning as a policeman of unique and superior characteristics. Though intended primarily for use at room temperatures, it may be used for short periods at temperatures up to 100 degrees centigrade.

- Available in two convenient lengths.
- Unbreakable and never causes scratching of glassware.
- Rod may be bent into any form to suit your requirements.
- Paddles can be trimmed with scissors or knife to any desired shape.
- Order your stock of NYLAB "Police Rods" today.

PRICES		
Cat. No.	Approximate Overall length, in.	Per dozen
83250	6	$3.75
83255	9	4.75

10% discount on gross lots

NEW YORK LABORATORY SUPPLY CO., INC.

76 Varick Street — New York 13, N. Y.

reprints available . . .

Following is a list of reprints of articles from the JOURNAL OF CHEMICAL EDUCATION in stock at the present time. Because supplies are limited, please state second choice.

No.	TITLE AND AUTHOR	PRICE
602	Business Organization and Administration in the Chemical Industry, F. Curtis	25¢
603	The Dynamics of Gas Flow, Worth H. Rodebush	25¢
605	Lecture Demonstration Experiments in Organic Chemistry, Ray Q. Brewster	25¢
606	Sodium Perchlorate and Anhydrous Magnesium Sulfate: Two Student Preparations, Sigfred Peterson	10¢
607	Selection and Performance of Students, Fred Hazel and H. Sherman Oberly	25¢
609	Wolfgang, Pauli, by Emery I. Valko	10¢
610	Metallic Soaps, Roy G. Bossert	25¢
611	The Rise of Industrial Research and Its Management, William A. Hamor	25¢
613	Storage Batteries, James E. Cassidy	25¢
614	Commercial Development in the Chemical Industry, F. J. Curtis	25¢
615	Technical Employment in the Chemical Industries, E. W. Cook	25¢
616	The Chemical Revolution—The Second Phase, Sidney J. French	25¢
619	An Improved Apparatus for Obtaining Boiling Points of Liquid Mixtures, Lawrence P. Eblin	10¢
620	Berzelius and Goethe, Dr. Oskar Baudisch	10¢
621	Chemical Education in Liberal Arts Colleges, 1934–48, J. R. Sampey	10¢
622	Element of the Week, Delmar K. Myers	10¢
626	First Day with Hercules, Jane F. Gaffney and John T. Hays	25¢
627	Importance of Functional Group Determination in Organic Quantitative Analysis, Sidney Siggia	25¢
628	Precipitation of Group II in Qualitative Analysis, John R. Long	10¢
629	The Training of Analytical Chemists for Industrial Research, J. Stillman	25¢
630	Research and Development in the Chemical Industry, F. J. Curtis	25¢
631	Organic Chemistry and the Analytical Program at M.I.T., Ernest H. Huntress, David N. Hume and Lockhart B. Rogers	25¢
632	Organic Analysis in the Chemistry Curriculum, Philip J. Elving	25¢
633	Unknowns for Molecular Weight Determination, H. D. Crockford	25¢
634	Hydrogen Demonstration Cannon Made of Glass, J. E. Ransford, S. J.	10¢
635	A Model Illustrating the Effect of Thermal Agitation, R. H. Woolley and Dan McLachlan, Jr.	25¢
636	Human Values in Engineering, Francis J. Curtis	25¢
637	Apparatus For Student Conductance Measurements, P. Bender, W. J. Biermann, and Alvin G. Winger	25¢
638	Methods for Constant Potential Control, E. B. Thomas and R. J. Nook	25¢
639	Tenney L. Davis and His Work in the History of Chemistry, H. M. Leicester and H. S. Klickstein	25¢

Journal of Chemical Education, Easton, Pennsylvania
For the enclosed remittance please send me the following reprints, carrying charges prepaid:

No.	Quantity	No.	Quantity	No.	Quantity
....	.....	....	.....	....	.....
....	.....	....	.....	....	.....
....	.....	....	.....	....	.....

Substitute numbers, if those above are not available.

....

NAME.....

ADDRESS.....

CITY.....ZONE.....STATE.....

Order by number. Postage stamps acceptable.

A Continuing University...

THE JOURNAL OF CHEMICAL EDUCATION is a continuing university for the teacher and for the chemist in industry. It is an open forum for the exchange of ideas and experiences, the value of which is apparent to chemists in industry as well as to all chemistry teachers.

Solutions to problems, improvements in technique and practice, new theories and ideas become common knowledge for the benefit and guidance of all.

While the JOURNAL is the chemistry teachers' own periodical its editorial columns are open and of interest to the industrial or research chemist also.

Not only does the JOURNAL feature articles pertaining to education and educational practices, such as teaching methods, educational studies and statistics, but . . . . it carries original papers from prominent educational and research chemists as well.

Its articles on new and revised laboratory procedure and technique, and on the construction of laboratory apparatus, are of value to all chemists.

Other articles in the JOURNAL, which are most often referred to by commentators, are its reviews of industrial processes and practices, and its historical and biographical sketches. Abstracts, book reviews and extended discussions of subjects impossible to include in textbooks are regular features.

These articles are clear, concise and authoritative. They are varied in topic and sufficiently non-technical to be of general value. They form a living textbook of chemistry—an invaluable source of material not to be found in reference volumes, or elsewhere.

Thousands of chemists and chemistry teachers use the JOURNAL in their own special way to meet their own special problems, and it is readily adaptable to a multitude of such uses. You too, will find the JOURNAL helpful, informative . . . . and highly readable.

*It is still only $3.00 a year**

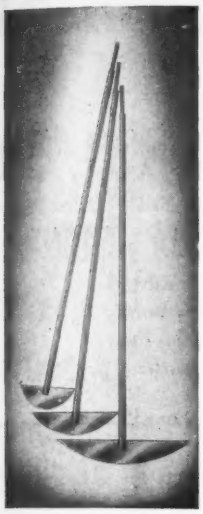
TRY IT!

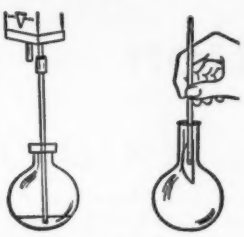
JOURNAL OF CHEMICAL EDUCATION

EASTON, PENNSYLVANIA

*In the U. S. A. Foreign $4.00 per year

Balanced Paddle Stirrers





* Easily Inserted in Flask
* Balanced . . . never whip
* Stainless Steel

Our new WACO Balanced Paddle Stirrers are easily inserted in the neck of the flask . . . never whip so your glass set-ups are safe!

All made with 300 mm. x 6 mm. shaft . . . the only difference is length of the paddle. Suitable for all popular sizes of flasks used in the laboratory.

No. 7298-JC. WACO Balanced Paddle Stirrers. Shaft 6 mm. x 300 mm. to fit 1/4" or 3/16" chuck. In boxes of 3 Paddles.
Blade 20 x 50 mm. — $2.00
" 20 x 75 mm. — $2.25
" 20 x 100 mm. — $2.35

No. 7298-JC. Conveniently packaged set of 3, one of each size **$6.00**

LABORATORY SUPPLIES AND CHEMICALS

WILKENS ANDERSON CO.

4525 W. DIVISION ST • CHICAGO 51 • ILLINOIS

LOOSE PLATE • TABLE TYPE

BUCHNER STYLE FUNNEL

A *New* PRODUCT BY **COORS**

COORS U.S.A. CHEMICAL AND SCIENTIFIC PORCELAIN WARE *Internationally Recognized for Quality*

Catalog No. 498

LOOSE PLATE CONSTRUCTION ALLOWS THOROUGH CLEANSING OF THE FILTERING COMPARTMENT

PLATES AND SEATS ACCURATELY GROUND

LIGHT WEIGHT • COMPACT • WELL BALANCED DESIGN

COORS PORCELAIN COMPANY
GOLDEN COLORADO

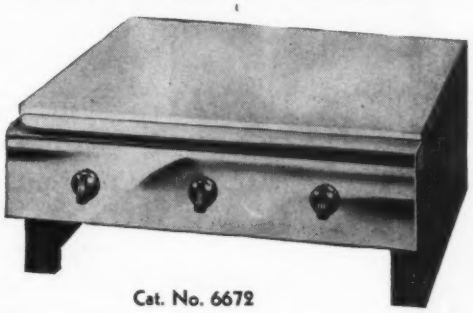
Designed Specifically for Laboratory Use...

GAS HOT PLATES

Low Initial Cost

Economical Operation

Ideal for Educational Laboratories



Cat. No. 6672

These improved gas hot plates provide economical and efficient operation . . . and are low in initial cost. Top is smooth boiler plate, 3/8" thick. Body is 20 gauge iron, brazed and spot welded into a rigid unit.

Burners are tubular cast iron, and are equipped with universal valves, adjustable for any type gas. Non-breaking metal valve handles provide easy control of burners. The attractive chrome plated front is resistant to corrosion, and is easily cleaned.

Made in four sizes; all with a height of 9 inches and an overall depth of 22 inches. The gas connection is from the left front.

Plate Size	9"x18"	18"x18"	24"x18"	30"x18"
No. of Burners	1	2	3	4
Price	$39.60	$52.80	$60.50	$68.20

Federal Excise Tax does not apply to these Hot Plates, since they are designed for laboratory use only.

CRC *The* **CHEMICAL RUBBER CO.**
2310 SUPERIOR AVE. CLEVELAND 14, OHIO

Handbook of Chemistry and Physics

SCIENTIFIC EQUIPMENT • LABORATORY SUPPLIES
ANALYTICAL CHEMICALS

WHAT'S NEW in the Second Edition

POLAROGRAPHIC METHOD OF ANALYSIS

By OTTO H. MÜLLER, *Associate Professor, State University of New York, Medical Center at Syracuse University, Syracuse, N. Y.*

In revising "Polarographic Method of Analysis," the author added much new material making the second edition virtually a new book. It has been completely reset, revised and enlarged to 209 pages. Following is a list of some of the new material added to this edition:

CHAPTER I Discussion of polarization, depolarizers, and sign of electrode potentials.

CHAPTER II Time saving apparatus and recording instruments and their wiring circuits.

CHAPTER III The analytical application of maximum suppression. Exaltation of current in absence of supporting electrolyte. Kinetic current and three possible ways in which it may be produced. Catalytic current and recent developments in this field.

CHAPTER IV Electrode deposition of metals from complex metal ions. Reaction of organic compounds in unbuffered solutions and demonstration of buffer action. In this a suggestion is made about using the method of buffer action as a method of the quantitative analysis of non-electroactive substance. Influence of temperature and solvent on the half wave potential. Reduction of hydrogen ions at the dropping mercury electrode.

CHAPTER V Polarometry is now treated as a separate chapter and has been extended.

CHAPTER VI is completely new. It treats such recent developments as differential polarography, derivative polarography and oscillographic polarography. Also in this chapter are discussed newer developments in electrodes which are used for polarographic analysis, such as the multiple dropping mercury electrode, the knock-off electrode, and the streaming mercury electrode and various forms of platinum electrodes, such as the stationary and rotating platinum electrodes, and the by-pass electrode.

CHAPTER VII is the old chapter 5, to which have been added method of standard addition, method of step quotients, pilot ions, and their use, the electrolysis prior to polarographic analysis, the anomolous wave and the protein index.

CHAPTER VIII In this chapter are discussed the various factors which may cause irregularities in polarographic curves. Also given is the information which makes it possible to characterize any given electrode and to select a capillary for a dropping mercury electrode with a desirable drop time and drop weight.

An *appendix* has been added in which are given the potentials of reference electrodes as well as a list of useful buffers for polarographic analysis. Finally, an *index* has been added which should make the book much more valuable than its predecessor.

209 pp **illustrated** **$3.50**

Order your copy today from

CHEMICAL EDUCATION PUBLISHING CO.

EASTON, PENNSYLVANIA

ALBERENE STONE

FOR LAB TABLE TOPS, SINKS AND HOODS

is

- highly resistant to chemicals
- essentially non-staining
- durable
- attractive
- suitable for construction of liquid-, gas-, and germ-proof joints

For full technical information, and for expert assistance in designing your laboratory, write Alberene Stone Corp. of Virginia, 419 Fourth Avenue, New York 16, N. Y., or visit our nearest branch office.

ANOTHER MODERN RESEARCH LAB equipped with Alberene Stone table tops and sinks . . . new SOLVAY LABORATORY, Solvay Process Division, Allied Chemical & Dye Corporation, Syracuse, N. Y. Architects—The H. K. Ferguson Company.

ALBERENE STONE

Branches in Principal Cities

AMEND DRUG & CHEMICAL CO., INC. — AMEND — NEW YORK, N.Y.

A New Special Type Detergent

ORONOX

Rust Inhibitor—Removes and prevents rust
Cleans and Brightens Instruments like new
Harmless to hands
Eliminates tedious scrubbing
Leaves no film

Write for Sample
$1^1/_2$ lb. box $1.95

The Best Detergent, Wetting Agent and Rust Inhibitor on the Market

AMEND DRUG & CHEMICAL CO., INC.
117-119 East 24th Street **New York 10, N. Y.**

Add this beautifully illustrated book to your chemistry library..

The CHEMICAL ARTS of OLD CHINA

by

Li Ch'iao-p'ing

Professor of Chemistry
National Northeastern University
Mukden, China

If you are a lover of beautiful books—and a chemist besides—you'll want to add a copy of *The Chemical Arts of Old China* to your personal chemistry library. You and your family will cherish this exquisitely designed and illustrated book.

Included in *The Chemical Arts of Old China* are copiously illustrated chapters on alchemy, metals, salt, ceramic industries, lacquer and lacquering, gunpowder, colors and dyes, vegetable oils and fats, incense, essential oils, and cosmetics, sugar, paper, leather and glue, soybean products, alcoholic beverages and vinegar . . . plus an appendix showing the dates of the Chinese Dynasties, and a list of Chinese weights and measures.

56 pen and brush drawings, and 22 halftone plates illustrate the ancient Chinese methods of producing salts, glazing porcelain, preparing gunpowder, manufacturing inks and dyes, preparing maltose, making paper, distilling spirits, etc.

Whatever *your* particular interest, you will find much to delight and intrigue you in Professor Li's book. Artistically designed cover and endpapers, English and Chinese title pages, and numerous illustrations, all contribute to the beauty of *The Chemical Arts of Old China*, and to your reading pleasure.

229 pp. $5.00 (postage prepaid)
($5.50) Foreign

Sweeping the salted ash into heaps after the sea water has evaporated.

Working the drainers for the preparation of concentrated brine.

Final crystallization of the salt.

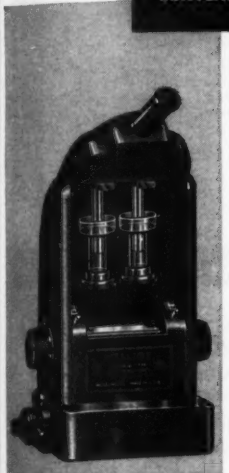
Order your copy today from

CHEMICAL EDUCATION PUBLICATIONS

2077 Northampton St. Easton, Pa.

HELLIGE-DUBOSCQ COLORIMETER

POSSESSING SURPASSING FEATURES OF CONVENIENCE, PRECISION AND DURABILITY



For research work, routine analyses, and diversified applications, the Hellige-Duboscq Colorimeter has proved its superiority in different branches of industry, engineering and science. It is also the ideal colorimeter for clinical tests as non-fading precision glass color standards are available for 36 bio-chemical tests. One of the special features is the five-fold increase in the drum scales which permits 0.1 mm readings without use of a vernier.

PROMPT DELIVERY

Write for Catalog No. 250

HELLIGE, INC. 3718 NORTHERN BLVD. LONG ISLAND CITY 1, N. Y.

HEADQUARTERS FOR COLOR STANDARDS AND COLORIMETRIC APPARATUS

Now available . . .

Acenaphthylene; Acetobromoglucose; Acetonedicarboxylic Acid; α-Acetylindole; 3-Acetylpyridine; Acetylthiocholine Iodide; cis-Aconitic Acid; Acridine Hydrochloride; Adenosine Diphosphate; Adonidine; Alanylglycine; Alkaloids; 4-Aminopyridine; Amylase; Anserine; Arachidic Acid; Arachidonic Acid; l-Argininamide; o-Arsenilic Acid; Atropic Acid; Bacitracin; Behenic Acid; Carbobenzoxychloride; Carnosine; Catalase cryst.; Cellulase; Cerotic Acid; Ceryl Alcohol; α-Chloralose; β-Chloralose; p-Chloroanilidophosphonic Acid; p-Chloromercuribenzoate; Cholesterol Esters; Circulatory Hormone; Clupein; Collagen; s-Collidin; Columbium Chloride; Copper Glycinate; Dehydroascorbic Acid; Desoxycorticosterone Glucoside; Desthiobiotin; Dialuric Acid; Dibromosalicylaldehyde; Dihydroxyacetone Phosphate; Diisopropyl Fluorophosphate; Dithiol; Endosuccinic Derivatives; Enzymes; Equilenin; Equilin; Erucic Acid; dl-Ethionine; Ethylenediamine Tetraacetic Acid; Ethylpyridinium Bromide; Fructose-6-Phosphate; Gitoxin; Glucoascorbic Acid; Glucosides; Glucuronides; Glyceraldehyde Phosphate; Glycylglycylglycine; Glycylleucine; Glycyltryptophane; Glycyltyrosine; Heparin; Hexokinase; Hyaluronic Acid; 4-Hydroxyacridine; β-Hydroxyglutamic Acid; α-Hydroxyphenazine; 12-Hydroxystearic acid; Iodoacetamide; o-Iodosobenzoic Acid; Isoascorbic Acid; Isocitric Acid; Isocytosine; Kynurenic Acid; Lactobionic Acid; Leucylglycine; Leucyltyrosine; Lignoceric Acid; Lithium Amide; Margaric Acid; Menthol Glucuronide; β-Mercaptopropionic Acid; Mescaline Sulfate; Mesocystine; Methyl-bis-Chloroethylamine; β-Methylcrotonic Acid; 3-Methylcytosine; Methylnonylketone; β-Naphthaleneacetic Acid; N-Naphthyl-N'-diethylpropylenediamine; Naphthyl Red; Neurine Bromide; Nitrosomethylurea; Nordehydroguaiaretic Acid; Osmic Acid; Parabanic Acid; Penicillinase; Peroxidase; Phenolphthalein Glucuronide; Phenylpyruvic Acid; Phosphopyruvic Acid; Phthiocol; Pregnenolone; Protocatechuic Acid; Purpurogallin; Pyocyanine; Pyrimidine; Reductic Acid; Sodium Amide; Sodium Fluoroacetate; Sphingomyelin; Sphingosine; Stilbamidine; Sulfaquinoxaline; Tantalum Chloride; o-Terphenyl; m-Terphenyl; p-Terphenyl; Thiomalic Acid; β-Tocopherol; γ-Tocopherol; β-Tocopherol Phosphate; γ-Tocopherol Phosphate; Trigonelline; Tropic Acid; Tyrosinase; Urease cryst.; Uridine; Urobilin; Ursolic Acid; Vitamin B_{12}.

Ask us for others!

DELTA CHEMICAL WORKS

23 West 60th St. New York 23, N. Y.

Telephone PLaza 7-6317

ELECTRONICALLY REGULATED

LABORATORY POWER SUPPLIES

• STABLE • DEPENDABLE • MODERATELY PRICED •

BENCH MODEL 25

WIDTH 14" DEPTH 6" HEIGHT 8" WEIGHT 17 LBS.

- **INPUT:** 105 to 125 VAC, 50-60 cy
- **OUTPUT #1:** 200 to 325 Volts DC at 100 ma regulated
- **OUTPUT #2:** 6.3 Volts AC CT at 3A unregulated
- **RIPPLE OUTPUT:** Less than 10 millivolts rms

For complete information write for Bulletin H8

LAMBDA ELECTRONICS CORPORATION

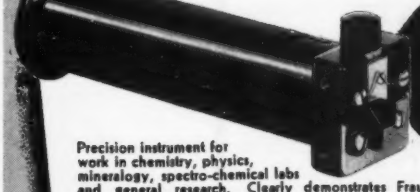
CORONA NEW YORK

NEW!

HAND SPECTROSCOPE

for Spectrum Analysis

with COMPARISON PRISM



$62.• Prepaid

Precision instrument for work in chemistry, physics, mineralogy, spectro-chemical labs and general research. Clearly demonstrates Frauenhofer Lines, Bright Line and Absorption Spectra. Incorporates 2 prisms. Spectra can be examined from 2 sources simultaneously. Used with bunsen burner, fluorescent tubes, daylight, Geissler tubes, sodium or mercury lamps. Table stand and test tube attachments available.

Fully guaranteed.

Write for Illustrated Factual Data

Your Name.....

Firm or school name.....

Address.....

City.....State.....

LABORATORY EQUIPMENT CO.

526 FOLSOM STREET • SAN FRANCISCO, CALIF.

EQUIPMENT APPARATUS

CHEM ED BUYERS' GUIDE

CHEMICALS SERVICES

FLEXIBLE PLASTIC TUBING

TOP QUALITY, MODERATELY PRICED

Nalge's Alanol flexible plastic tubing is tough, clear and chemically inert. Can be used for corrosive chemicals, alcohol, food products, beverages and oils. Sterilizable with steam, it is made of a Vinyl Chloride Compound and stocked in 37 sizes from .120 to 1 inch i.d., 170 to 1⅜ inches o.d. Temperature range is minus 35 to plus 190 degrees F.

Ask us for prices and quantity discounts, they will show large savings over competitive products. Samples supplied.

The NALGE Company
623 S. Goodman St., Rochester 20, N.Y.

ARE YOU LOOKING FOR A PUBLISHER?

Our policy is to encourage new, unknown writers. If you are seeking a publisher of your laboratory manual, specialized textbook, novel, scholarly work, poetry, etc., perhaps we can help you. Write for Free Booklet JC. Address request to Mr. Charles Jed.

Vantage Press, Inc., 230 W. 41st St., New York 18

Cargille
Micro Beakers

Leaflet on Request

Price: $7.50 per Gross; Plastic Holder $.50; or send $2.00 for 24 assorted Beakers with Plastic Holder as illustrated.

R. P. CARGILLE
118 Liberty St. New York 6, N. Y.

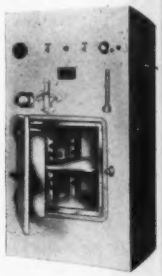
New 'BIOS' Chemicals

IMMEDIATE DELIVERY from complete stocks

Alkaloids
Natural and Synthetic Amino Acids
Unnatural Amino Acids
Biochemicals
Enzymes and Coenzymes
Heterocyclic Compounds
Imines and Amines
Metalorganics
Pharmaceuticals
Purines and Pyrimidines
Rare Organic Acids and Derivatives
Reagents
Sugars and Derivatives
Vitamins and Derivatives

BIOS Laboratories, Inc.
17 West 60th St., New York 23, N. Y.
Plaza 7-8171

Hotpack NEW TABLE MODEL
Mechanically Convected OVEN



A table model mechanically convected oven with automatic temperature control uses a minimum of table space. The interior dimensions of the chamber are 12" wide × 14" deep × 14" high, but the exterior dimensions are only 23" wide × 20" deep × 40" high. Thus the new HOTPACK Mechanically convected oven takes up 50% less table space than the ordinary comparable table model, mechanically convected unit. The floor of the working chamber is just 9" above the table making it easy to load and unload, and all controls are located above and out of the way of the working chamber, yet within easy reach for adjustment.

- **Temperature range 35°C. to 180°C, plus or minus ½°C.**
- **Stainless steel interior, exterior finished in grey enamel.**
- **LIMITSTAT, provides extra safety temperature control.**
- **Built-in Thermometer set for eye level control.**

Send for detailed Bulletin.

THE ELECTRIC Hotpack CO., INC., 5097 COTTMAN ST., PHILA. 35, PA.

STAINLESS STEEL TANKS

Surplus stainless steel oxygen tanks. Rated for 400 psi, nine gallon 12" dia. x 24" long, two ¼" pipe connections, 19 lbs., $15 ea. FOB. Also, 104 cu. in. stainless tank 5" dia. x 8" long one ¼" pipe connection, 1½ lbs., $5 ea. FOB.

Ireland & Vice, Box 146J, Auburn, N. Y.

DL-2-Aminopropanol-1
3,4-Benzpyrene
Decamethylene Dicarboxylic Acid
Nonamethylene Dicarboxylic Acid
Tetraiodoethylene

EDCAN LABORATORIES
South Norwalk, Connecticut

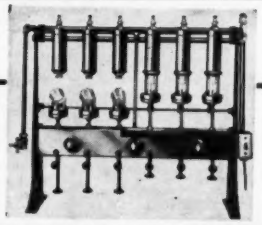
Write for QUANTITY PRICES on QUALITY APRONS

SCHOOL PRODUCTS CO.
111 Hudson Street, N. Y. 13

NINHYDRIN

Reagent for
AMINO ACIDS

PIERCE CHEMICAL COMPANY
P. O. Box 117 Rockford, Ill.



"GOLDFISCH" FAT EXTRACTOR

Automatic release-and-seal features to speed your solvent extraction and reclaim high percentage of solvent. Used by 29 states in feed control work and by hundreds of diversified school and industrial laboratories. Made in 2, 4, and 6 capacity units. No change need be made in your present extraction methods—and you'll save time and solvent!

WRITE DIRECT TO THE MANUFACTURER FOR PICTURES, PRICES, FULL DETAILS

LABORATORY CONSTRUCTION CO.
1113 Holmes Street • Kansas City, Mo.

ORGANIC NITROGEN COMPOUNDS
FUNDAMENTAL ORGANIC CHEMISTRY
WORK-BOOK OF ORGANIC CHEMISTRY
Revised: $3.75, 4.50, 1.75
University Lithoprinters,
Ypsilanti, Michigan

BROOKFIELD
Synchro-Lectric
VISCOMETER

Makes accurate viscosity determinations in less than 30 seconds — as simply, quickly, easily as taking temperature.

BROOKFIELD
Counter-Rotating
MIXER

Two concentric, oppositely rotating shafts, propeller equipped, produce up to 48,000 scissor-like cuts per minute.

Write for fully descriptive literature.

Brookfield ENGINEERING LABORATORIES, INC. 215 Parker St., Stoughton, Mass.

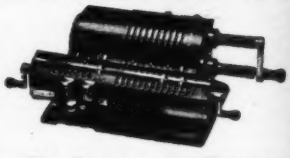
AMINO ACIDS—RESEARCH BIOCHEMICALS

Basic Producers of HYDROXYPROLINE
PROLINE, ARGININE
L- and D- ISOMERS, ETC.

Write for our Catalogue

H. M. CHEMICAL CO., LTD.
1651—18th St., Santa Monica, Calif.

SINCE 1874
ORIGINAL ODHNER
HANDY CALCULATOR



For The Chemist and Engineer

Sturdy: Low Priced: Weight 12 lbs.
Easy to Learn: New Back Transfer Device Speeds Up Calculations

Ask For Bulletin CQ-83

SOLE DISTRIBUTORS FOR U. S. A.
IVAN SORVALL, INC.
210 FIFTH AVE., NEW YORK 10, N. Y.

ADVERTISERS' INDEX

Alberene Stone Corp. of Va.... 35
Amend Drug & Chemical Co., Inc..... 35
American Balance Corp..... 18
Angel & Co., Inc., H. Reeve.. 31

Baker & Adamson Products (Gen. Chem. Div., Allied Chem. & Dye Corp.)..... 12
Baker Chemical Co., J. T.... IFC
Burrell Corp..... 40

Central Scientific Co..... 6
Chem Ed Buyers' Guide..... 38
Chemical Rubber Co..... 33
Coleman & Bell Co., Inc..... 30
Coleman Instruments.....24 & FC
Coors Porcelain Co..... 33
Corning Glass Works..... 19

Delta Chemical Works..... 37

Eaton-Dikeman..... 30
Eberbach & Son Co..... 18

Farrand Optical Co..... 24
Fisher Scientific Co..... BC

General Laboratory Supply Co. 25
Greiner Co., Emil..... 15

Hammond Drierite Co..... 25
Harshaw Scientific Co..... 17
Hellige, Inc..... 37
Hevi Duty Electric Co..... 39

Kewaunee Mfg. Co..... 29
Kimble Glass..... 16
Klett Mfg. Co..... 26

Laboratory Equipment Co.... 37
Lambda Electronics Corp..... 39
LaPine & Co., Arthur S..... 13

McGraw-Hill Book Co., Inc... 8
Macmillan Co., The..... 9
Mallinckrodt Chemical Works. 7
Matheson Co., The..... 26
Merck & Co., Inc..... 11

New York Laboratory Supply Co., Inc..... 31

Ohaus Scale Corp..... 10

Parr Instrument Co..... 24

Radiation Counter Laboratories, Inc.....IBC
Reinhold Publishing Corp..... 4

Sargent & Co., E. H..... 14
Saunders Co., W. B..... 23
Schleicher & Schuell Co., Carl. 28
Scientific Glass Apparatus Co., Inc..... 28
Standard Scientific Supply Corp..... 20

Thomas Co., Arthur H..... 3

U. S. Stoneware Co..... 27

Welch Scientific Co., W. M.... 22
Wilkens Anderson Co..... 33

HEVI DUTY *Multiple Unit*

HOT PLATES

are essential in your Laboratory Set-up!

Widely Used in Laboratories for:

- HEATING AND EVAPORATING SOLUTIONS
- ALCOHOL AND ETHER EXTRACTIONS
- DRYING OF PRECIPITATES
- DISTILLING, BOILING, ETC.

"MULTIPLE UNIT" Hot Plates are available in seven standard sizes, all equipped with three heat switches for temperatures to 750° F. Special sizes can be made to meet your particular requirements. Because of the uniform distribution of the heating elements, there is an even temperature over the entire top surface. The heating units are readily replaceable by the user resulting in economy of maintenance. For complete details,

SEE YOUR LABORATORY SUPPLY DEALER
or write for Bulletin HD-835

HEVI DUTY ELECTRIC COMPANY

LABORATORY FURNACES **MULTIPLE UNIT** ELECTRIC EXCLUSIVELY

TRADE MARK REG. U. S. PAT. OFF.

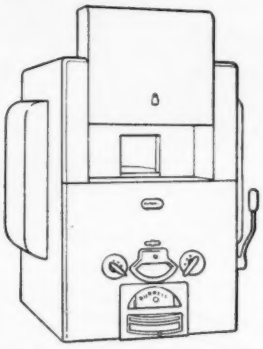
MILWAUKEE 1, WISCONSIN

FOR SCIENTISTS EVERYWHERE

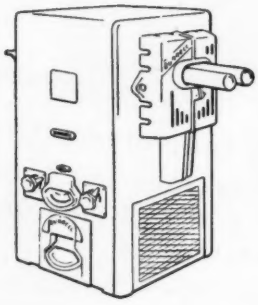
ELECTRIC FURNACES

by BURRELL

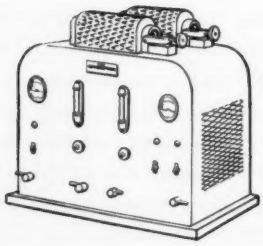
To you—the chemists, metallurgists and laboratory technicians with whom we have been privileged to work through the years—belongs the credit for Burrell's leadership as a supplier of electric furnaces for analysis, control and production. You told us your needs; we developed apparatus to meet those needs. As a result of this cooperation, many improvements have been made for easier operation, greater safety and dependable operation. Today, Burrell offers as comprehensive a line of high and low temperature furnaces as can be found in any one source.



BURRELL UNIT-PACKAGE BOX AND MUFFLE FURNACES are designed for either low or high temperature operation. In a range from 600° F. to 2000° F., you can perform efficiently such functions as ashing, drawing, igniting, tempering. Above 2000° F. and on into the high white, these versatile units are equally adaptable for such services as sintering, melting, clinkering, fusing and high speed hardening. All are ruggedly built and easily operated. Temperature control is automatic. Burrell Bulletin No. 315 provides all needed data about five different models.



BURRELL UNIT PACKAGE TUBE FURNACES are for determining carbon or sulfur in ferrous analysis and any other similar procedures which require continuous operating temperatures up to 2650° F. Various models are offered to answer individual requirements for limited use, average use or high speed production. All are self-contained and fully equipped furnace units, ready for connection to your power supply. They are easy to install and simple to operate and will reward users with long, trouble-free service. Ask for Burrell Bulletin No. 310.

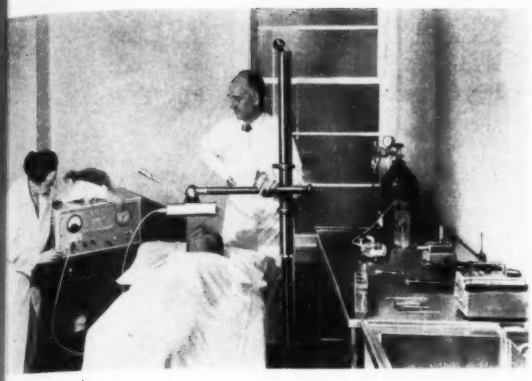


BURRELL COMBUSTRON is a new high frequency induction heater for rapid determination of carbon-by-combustion analysis in steel. Accuracy with coarse, fine or pin-type samples has been proved by extensive tests. The Combustron is always ready for continuous or intermittent use. It is a self-contained, fully equipped instrument ready to plug into the power supply and put to immediate use. No pre-heat time is needed; you insert the sample and snap the switch. A one tube model is offered for average use, a two-tube model for heavier production. Write for Burrell Bulletin No. 319.

BURRELL CORPORATION

2223 FIFTH AVENUE, PITTSBURGH 19, PENNSYLVANIA

MANUFACTURERS AND DISTRIBUTORS OF SCIENTIFIC APPARATUS AND LABORATORY CHEMICALS



A radioisotope laboratory using radioiodine in the treatment of hyperthyroidism.

Pamphlet available.

Basic counting equipment widely used in making quantitative measurements by means of a Fusion Seal Mica Window Counter.

Radioisotope Users

For the radioisotope user this page shows actual laboratory scenes. Radiation Counter Laboratories, Inc., specializes in making all equipment for the measurement of radioactivity. Its large staff of experienced physicists, chemists, electronic and mechanical engineers, glassblowers, and technicians are ever ready to meet your needs. For recommendations write today for Information Bulletin No. 10.

RADIATION COUNTER LABORATORIES, INC., DEPT. CE.

1844 West 21st Street **Chicago 8, Illinois**

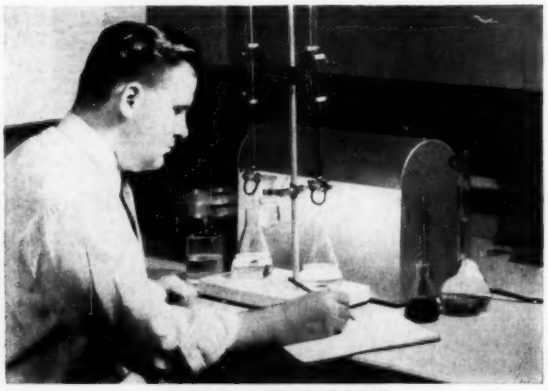
The Nucleometer permits use of Geiger counting, proportional counting, and scintillation counting all with a single investment. Here is shown a Nucleometer-Scaler Type using a Preflush Flow Counter.

Health protection is basic in handling radioisotopes. Shown here is the RCL Alpha, Beta, Gamma Survey Meter so useful in looking for spills.

WHATEVER THE LABORATORY NEEDS

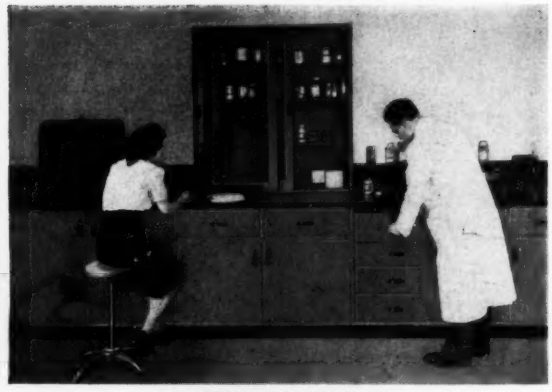
Laboratories have at their command from Fisher Scientific Company all of their day-to-day requirements and a large number of modern instruments, apparatus and chemical reagents not obtainable elsewhere.

INSTRUMENTS



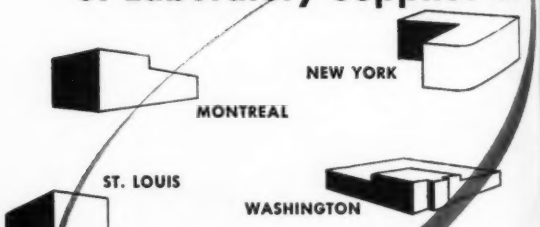
APPARATUS

REAGENTS



FURNITURE

Comprehensive Stocks
of Laboratory Supplies at



Headquarters for Laboratory Supplies

FISHER SCIENTIFIC COMPANY

PITTSBURGH •	NEW YORK •	WASHINGTON •	ST. LOUIS •	MONTREAL
717 Forbes (19)	635 Greenwich (14)	7722 Woodbury (Silver Spring, Md.)	2109 Locust (3)	904 St. James